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TECHNICAL REPORT

Contract No. FA-WA-4409
Project No. 430-001-01R

ANALYSIS OF COMMUNITY AND AIRPORT RELATIONSHIPS/NOISE ABATEMENT

Work Accomplishments
May 1963 Through April 1964

VOLUME II

DEVELOPMENT OF AIRCRAFT NOISE COMPATIBILITY CRITERIA FOR VARIED LAND USES

DECEMBER 1964

This report has been approved for general availability

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Prepared For

FEDERAL AVIATION AGENCY
Systems Research And Development Service

by

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DEVELOPMENT OF AIRCRAFT NOISE COMPATIBILITY CRITERIA FOR VARIED LAND USES

December 1964

Prepared by

DWIGHT E. BISHOP

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ABSTRACT

FIRST YEAR'S WORK ACCOMPLISHMENTS

This report is one of three separate reports that together document engineering and research activities undertaken during the first year of a two-year effort. The effort is directed towards determining the technical basis and procedures for assessing and predicting community response to noise. Separate reports were identified from the originally conceived composite report because the diversity of subject matter made it unlikely that any one reader would have interest in all topic areas. However, to insure as wide a dissemination of information as possible, a comprehensive abstract and preface have been included with each of the individual reports. The abstract reviews all three separate reports. The preface presents an overview of the entire two-year work effort.

VOLUME II

This report describes two simplified procedures for analyzing aircraft noise in the vicinity of airports to determine:

(a) whether or not aircraft noise will interfere with work activities or land use, and

(b) what building arrangements and construction features should be incorporated in building design so that aircraft noise will not interfere with planned activities inside buildings.

The first procedure is general in nature and defines aircraft noise acceptability criteria for broad categories of land use (residential, commercial, industrial, etc.). The second procedure provides methods for developing aircraft noise criteria for specific work activities having varying degrees of dependence upon speech communication or freedom from noise interference; it also specifies methods for evaluating the noise protection afforded by different types of building construction and building arrangements.

Both procedures make use of the noise level information given in the report, "Land Use Planning Relating to Aircraft Noise," previously submitted to the FAA. Thus, this report extends methods for evaluating aircraft noise compatibility to land uses other than residential, considered in the earlier report.

The report contains detailed descriptions of each step in the procedures, plus several examples of the application of the procedures to land use and building arrangement and design.

VOLUME I

Development of a computer-aided approach to the analysis of aircraft noise as it affects communities near airports is summarized in this report. The major factors that must be described to specify the noise stimulus and the factors which appear to be relevant to description of the community-wide response to that noise are discussed and diagrammed. An approach to analysis of aircraft noise situations that involves close man-computer interaction is formulated and programming to implement this approach is described. Some illustrations of the process are presented.

The major computer programs being developed will: (a) calculate perceived noise levels from octave band noise spectra; (b) calculate areas from graphical input data (maps, noise contours); (c) calculate and display noise contours for a simulated aircraft flight; (d) calculate the time pattern of noise exposure at a ground position near an aircraft flight path; and (e) calculate and assemble the noise levels occurring at multiple ground positions during a number of simulated aircraft flights.

VOLUME III

This report discusses legal aspects helpful in understanding some of the actions taken by individuals or by groups in a community responding to aircraft noise. Possible legal actions, with an assessment of the probability of successfully sustaining legal action, are discussed in terms of the physical relationship of aircraft and the ground observer, and the type of noise exposure which is likely to be encountered with current commercial aircraft operations.

ANALYSIS OF COMMUNITY AND AIRPORT RELATIONSHIPS/NOISE ABATEMENT

PREFACE

FIRST YEAR'S WORK ACCOMPLISHMENTS

Problems of measurement of aircraft noise and of predicting individual or community response to noise have been of concern to many during recent years. During this time considerable study of various aspects of the noise problem has been undertaken. Previous studies have investigated, in varying degrees of depth, such aspects as: methods for reducing aircraft engine noise at its source; laboratory psycho-acoustic studies of the subjective ratings of aircraft noise; public opinion surveys to gain insight into the way people feel about aircraft noise; engineering techniques for measuring the noise produced by aircraft; engineering methods for describing the noise environment; and methods for estimating community response to different degrees of noise exposure.

This two-year applied research project is directed towards gaining better understanding of why and how communities react to noise and to determining the feasibility of developing improved methods for predicting community response to noise. Because of the diverse factors to be considered, involving engineering, psychological and sociological considerations, and the varying depth of previous studies, several levels and directions of effort are required.

The work tasks can be grouped in terms of six general tasks as stated in the contract work statement:

(1) Determination of aircraft noise stimulus

(2) Determination of subjective ratings

(3) Analysis of overt actions and community action potential

(4) Consideration of land use and zoning - present and potential

(5) Development of in-house capabilities for the evaluation of the reactions to the sonic boom

(6) Overall analysis and conclusions.

The first four of the above tasks represent efforts in separate technical areas; they represent activities that, to varying degrees, can be carried out independently. The fifth task is a special consulting task not related to the others. Task 6 involves analysis and integration of work accomplished on the other tasks.

This report, the first segment of a two part final report, contains as Volumes I, II and III, separate technical reports describing results of investigations completed during the first year of the project in several of the technical areas. Thus, each of Volumes I, II and III contains technical information applicable to one or more aspects of the aircraft noise problem.

Volume I of this report (describing work accomplished under Task I above) provides a review of the noise problem and describes an approach to analysis of aircraft noise problems using computer-aided analysis and simulation techniques. Volume II of the report (developed as part of Task 4) describes procedures for analyzing the noise environment near airports to determine compatibility for varied land uses. Volume III of the report presents a discussion of various legal aspects of aircraft noise; this discussion provides background information needed in understanding airport-community relationships, under study as part of Task 3.

Work effort, continuing into the second year of the project life, is being devoted to completion of separate technical studies (psychoacoustic field experiments, community decision-making studies, and comparisons of noise environment with land uses) and preparation of an overall summary technical report. In this summary report, results of the varied project efforts are to be reviewed and analyzed. The presentation will provide unified discussions of technical guidelines for estimating the response of communities to airport noise, and the feasibility of improving existing prediction methods for estimating the response of communities to aircraft noise. Improved prediction procedures, if found to be feasible, will be described in this report, together with a review of the pertinent verification studies.

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DEVELOPMENT OF AIRCRAFT NOISE COMPATIBILITY CRITERIA FOR VARIED LAND USES

I. INTRODUCTION

The impact of aircraft noise on the development and use of land near airports has caused serious and continuing problems in many communities. Effective land use planning has been limited by lack of knowledge of what noise levels to expect with future type of aircraft and rapidly changing aircraft operations; there have also been problems of noise measurement and of interpreting the noise in terms of its probable effect on people and on the varied activities of people. All of the scientific and technical problems have not been solved, and many of the hazards of making long range forecasts in a rapidly developing field of technology still remain. However, sufficient studies have been undertaken in recent years to permit the development of practical engineering guides for estimating the influence of aircraft noise on many important work tasks and activities.

This report presents simplified procedures for comparing varied land uses and work activities with the noise exposure at different positions in the vicinity of airports to determine:

(a) whether or not aircraft noise will provide serious interference with work activities or land use,

or:

(b) what building arrangement and construction features should be considered in the building design so that aircraft noise will not interfere with the planned activity within the building.

To answer the two questions stated above, the report outlines two procedures: a general procedure defining noise compatibility criteria for broad categories of land use (residential, commercial, industrial, etc.); and a more detailed procedure for developing noise compatibility criteria and selecting building construction for specific work activities.

The general procedure should be of interest to those concerned with the planning and development of compatible land uses around airports, such as airport operators, land planning and zoning officials, land developers, and those governmental officials (local, state, and federal) concerned with urban planning, urban renewal, or the development of public airports in the United States.

The detailed procedure provides a relatively simple means for systematically interpreting the building noise reduction requirements* in terms of building construction and arrangement. One may obtain, early in the preliminary design stage, an idea of the economic penalties which may be involved in housing certain work activities in land areas exposed to high levels of aircraft noise. It should interest those responsible for locating, designing, and constructing specific facilities and who are faced with the problem of minimizing the effect of aircraft noise on the intended uses of the facilities. These people include architects, engineers, and land developers.

The procedures have been developed so that they may readily be used by those without specialized acoustic training. To facilitate use for planning purposes where detailed noise environment information is usually lacking, the procedures use a single number description of the noise magnitude, the perceived noise level, to describe both the intruding aircraft noise and the work activity criteria.**

An earlier report, "Land Use Planning Relating to Aircraft Noise,"1/ available from the FAA, describes procedures for judging the compatibility of aircraft noise with respect to

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* The term "noise reduction" is used in this report to denote the difference between noise levels observed outside and inside a building when the building is exposed to a source of noise located outside of the building.

** The perceived noise level expressed in PNdB is a quantity calculated from measured noise levels that correlates very well with one's subjective response in terms of annoyance and noisiness to various kinds of aircraft noise. It is widely used in this country and abroad as a measure of aircraft noise. See Reference 2 for tables and calculation procedures.

residential living. In contrast, this current report complements Reference 1 by making use of the noise information given in the earlier report to provide methods for judging the compatibility of aircraft noise for a wide range of human activities.

Figure 1 lists the steps in the procedure: five steps are listed in the general land use compatibility procedure; five additional steps are required for examination of specific room or building noise reduction requirements. Section III provides a detailed explanation of each step in the procedure, while the following section (Section IV) offers several detailed examples of the application of the procedures in solving land use problems.

Preceding the detailed explanation of the procedure steps, Section II discusses some considerations underlying development of the procedures.

Three appendixes are attached. Appendix A provides aircraft noise level information in the form of noise contours, (reprinted from Reference 1) which is directly useful in determining the aircraft noise exposure. Appendixes B and C describe the technical basis for development of certain data given in the report; reading of these appendixes is not essential to the understanding or the application of the procedures.

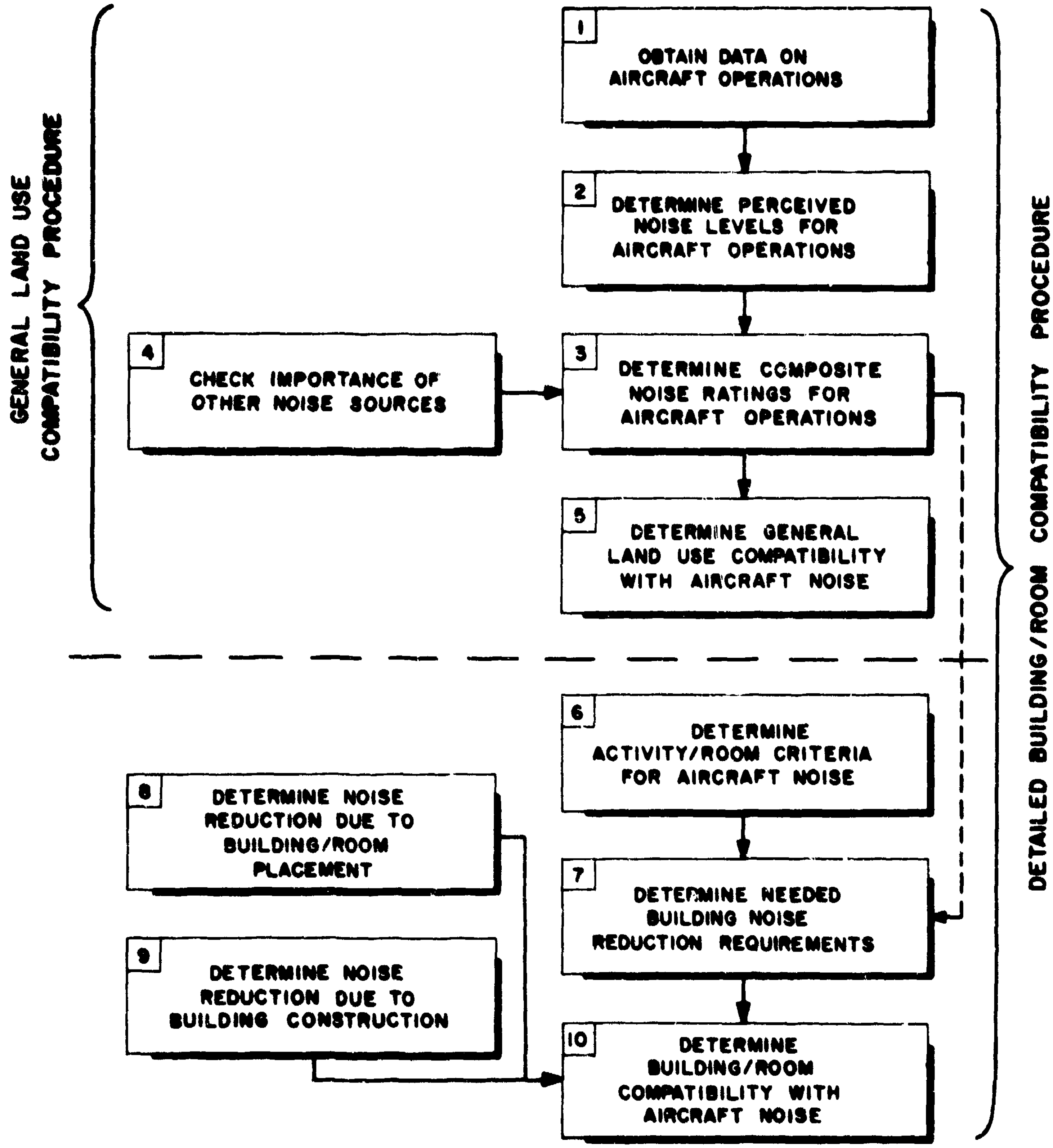


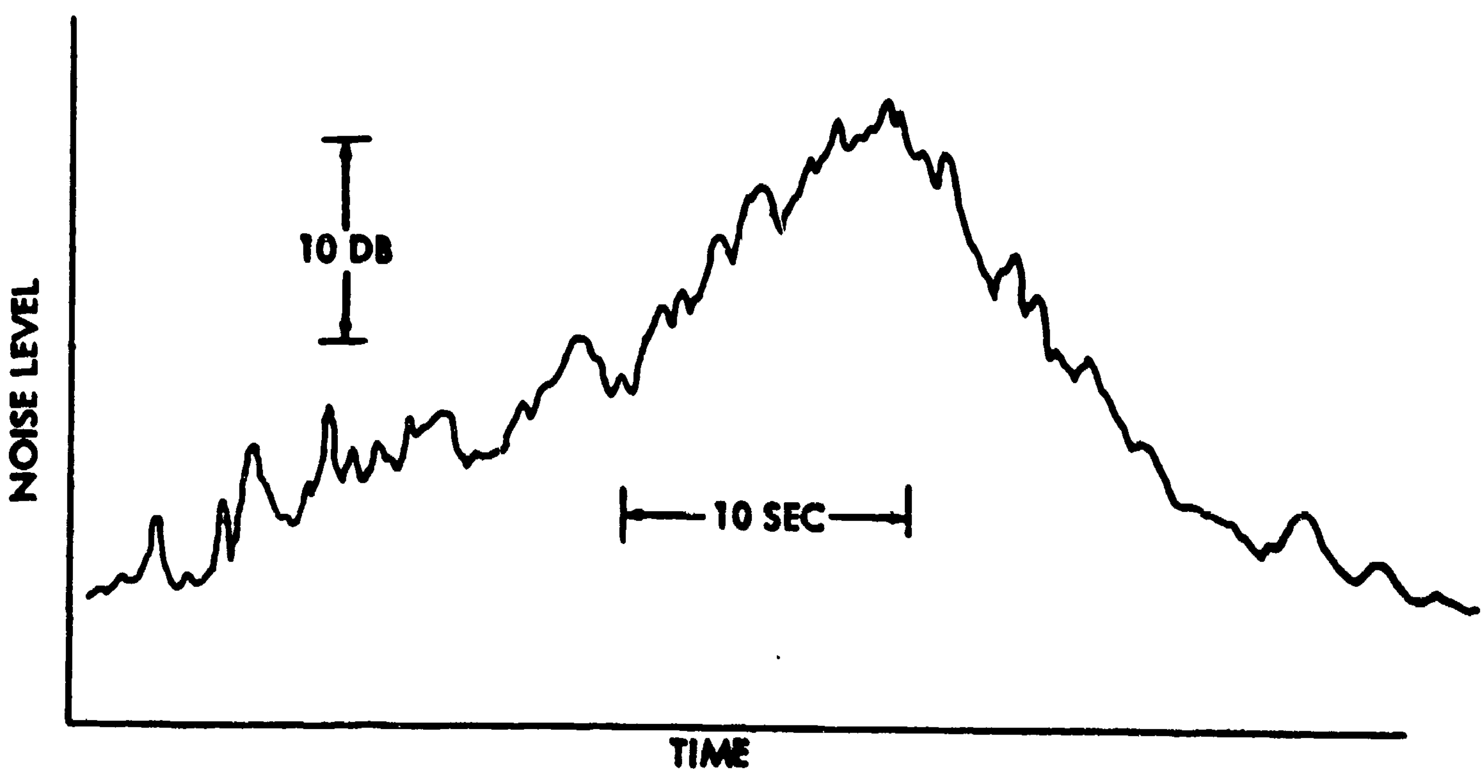
FIGURE 1. STEPS IN PROCEDURES FOR EVALUATING LAND USE COMPATIBILITY WITH AIRCRAFT NOISE

II. APPROACH

A. Need for Procedures

Why are specialized procedures needed to establish compatibility criteria for aircraft noise? Various noise criteria can be found for judging the acceptability of various types of steady-state noise environments for different work activities.[3,4] Likewise, information can be found concerning the noise reduction provided by different types of building construction, and the many architectural acoustic design considerations involved in the design of building and rooms to meet specific noise control needs.[5,6,7,8]

Perhaps the major consideration setting aircraft noise apart from many other types of "background" noise is that the noise signal produced by aircraft flyovers is essentially a transient, producing relatively high noise levels (often considerably higher than that produced by other transportation vehicles) for periods of seconds during a flyover, as illustrated by the following sketch.



TYPICAL TIME RECORD OF NOISE LEVELS DURING AN AIRCRAFT FLYOVER

The construction costs for providing the amount of noise reduction needed to ensure that aircraft noise cannot be heard inside a building will often be prohibitively large. On the other hand, since aircraft flyover noise is usually of short duration, it may often intrude appreciably without limiting or reducing the efficiency of many work activities. Considering the broad spectrum of human activities with their varying sensitivity to interruptions from short duration noise, and the costs of controlling aircraft noise levels, there is a need for procedures which account for the transient nature of aircraft noise and which evaluate the effect of this noise on varied human activities.

B. Problem Definition

Any noise problem may be stated in terms of three basic components, the noise source, the propagation path and the receiver. In determining land use compatibility, we are concerned with these three components stated in terms of (a) the noise environment existing outside a building at a given location in the vicinity of the flight path or airport, (b) the noise reduction afforded by the building, considering building construction, building orientation and room layout, and (c) the noise sensitivity of the receiver interpreted in terms of noise criteria based upon the work activity and importance of speech communication (or freedom from noise interruption) to that activity.

By subtracting the building noise reduction from the noise environment estimated outside the building, we obtain an estimate of the noise level inside the building. This value may then be compared with the noise criterion so that one may judge whether or not the noise will interfere with the work activity. Alternatively, the value of the noise criterion may be subtracted from the outside noise level to yield an estimate of the needed noise reduction which must be provided by the building construction, building orientation, room layout, etc.

Noise information can be gathered from a variety of sources, including by direct measurement. The procedures in this report are designed to complement the noise information and estimation procedures given in Reference 1. However, information from other sources when stated in terms of the perceived noise level may also be used without modification of procedures.

In some instances aircraft noise may not be the only noise source of importance; noise from other transportation vehicles, from neighbors, or that generated by internal work activities may be appreciable. The procedures are designed so that other noises, either intermittent or continuous, may be compared with the intruding aircraft noise to determine which noises are most critical.

The selection of appropriate criteria for aircraft noise is based upon established criteria for steady-state noise with the addition of adjustment factors for the transient nature of aircraft flyover noise. These adjustment factors are based upon consideration of the effects of intermittent noise on speech communication, and take into account the frequency of occurrence and the importance of speech communication to the given work activity.*

Emphasis on interpreting criteria in terms of speech communication lies in the importance of speech communication for many human activites, and in the fact that objective criteria for assessing the effect of noise on speech intelligibility exist.[9,10,11,12]

Of course, noise affects human activities other than speech communication. The noise environment may generate feelings of annoyance and irritability; noise may interfere with concentration on work tasks, with rest and sleep, etc.** Unfortunately, the relationships of noise with many of its subjective effects are not known; objective ways of estimating the degree of influence of noise on most of these attributes are lacking.[13]

The simplified procedures given here should not obscure the fact that when relatively high values of building noise reduction are required, calling for other than conventional lightweight construction, numerous building design details

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* These adjustment factors also provide a means for developing appropriate aircraft noise criteria for those activities where factors other than speech communication must be considered in evaluating the effect of noise intrusion (see Step 6).

** The noise levels of concern in this report are generally not high enough to produce serious physiological effects such as a permanent loss in hearing acuity.[13]

must be incorporated to achieve the desired noise reduction. Where extremely high noise environments and/or extremely low noise sensitivity criteria are involved, special noise control analysis based upon more detailed descriptions of the noise spectrum (such as octave- or one-third octave band frequency analysis) will usually be needed. In such cases, the procedures given in this report should be viewed as adequate for providing preliminary design estimates, but insufficient and incomplete to assure achievement of design objectives.[5,6,7,8]

III. DESCRIPTION OF PROCEDURES

The procedures for estimating land use compatibility with aircraft noise are described in this section step by step, following the steps and sequence shown in Fig. 1. To demonstrate the application of each step in the procedure, a running illustration will be inserted throughout the course of the text.

For convenience, sets of perceived noise level contours and tables used in Steps 1 and 2 to calculate perceived noise levels and Composite Noise Rating (CNR) contours are given in Appendix A; this information has been extracted directly from Reference 1.

Step 1 - Obtain Data on Aircraft Operation

The first step in the procedure is to obtain a description of the aircraft operations expected at the airport under study. For flight operations, information is required by aircraft type on the number of takeoffs and landings, on the percentage utilization of each runway, and on the flight paths used. For runup operations, information as to the type of aircraft (or engine) involved, location of the runup area, aircraft (or engine) orientation, and nature of the runup operation is needed.

A suggested form for collecting the required information on takeoff and landing operations and runway utilization is given in Table I.* The activity in Table I is expressed first in terms of the total number of movements occurring in the daytime or nighttime periods; then, in adjacent columns the activity information is converted into rates, expressed as the number of movements per hour. When one is concerned mainly with determining general land usage compatibility, activity information should be gathered for both daytime (0700-2200) and nighttime (2200-0700) periods and then after conversion to hourly rates, the higher of the two rates should be used for later calculations. When one is most concerned with determining building noise reduction requirements for specific work activities occurring on a

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* This table has been adapted from Table I of Reference 1, and is divided into aircraft categories identical to those given in that report.

TABLE I

SUGGESTED FORM FOR COLLECTING INFORMATION ON TAKEOFF AND LANDING OPERATIONS AND ON RUNWAY UTILIZATION

Aircraft Category	Aircraft Type*	Average No. of Movements		Average No. of Movements Per Hour		Percent Runway** Utilization			
		0700 to 2200	2200 to 0700	0700 to 2200	2200 to 0700				
	TAKEOFFS								
CIVIL	Turbojets-Trips under 2000 mi								
	Turbojets-Trips over 2000 mi								
	Turbofans-Trips under 2000 mi								
	Turbofans-Trips over 2000 mi								
	Four-Engine Piston								
	Four-Engine Turboprop								
	Helicopters (Sikorsky S-61, Vertol 107, and Vertol 44)								
MILITARY	Jets - Flight Group 1***								
	" " 2								
	" " 3								
	" " 4								
	" " 5								
	" " 6								
	" " 7								
	" " 8								
	" " 9								
	" " 10								
	Four-Engine Piston								
	Four-Engine Turboprop								
	LANDINGS								
CIVIL	Four-Engine Piston and Turboprop								
	Turbojet and Turbofan								
	Helicopters - Vertol 44								
	Helicopters - Vertol 107, Sikorsky S-61								
MILITARY	All Jets								
	Four-Engine Piston and Turboprop								

* Other designations for aircraft types are as follows: pure jet for turbojet; prop jet for turboprop; fan jet for turbofan; and conventional or propeller for piston engine.

** Runways are designated by their magnetic headings (with the last digit dropped). For example, Runway 9-27 is an east-west strip where takeoffs on R/W 9 are to the east, and landings on R/W 9 are from the west. Therefore, takeoffs on a given runway and landings on the reciprocal runway will usually pass over the same area. It is suggested that as many columns be allowed here as there are active runways to be considered.

*** Group classifications for individual military aircraft are given in Table A-1 in Appendix A.

well-defined time schedule, one would express the activity information in terms of the average flight activity for the period of concern. Thus, if one were concerned with design of an office where working hours extended from 0800 to 1800 hours, one would determine the hourly activity rate from the total number of flight operations in the period of 0800 to 1800 hours.

Although the list of aircraft categories in Table I appears lengthy, data would be gathered for all of them only at those installations where civil and military operations occur jointly. Also, when an airport has several active runways and the problem at hand concerns a single area located close to one runway, data need not be gathered for runways or flight paths whose operations obviously do not affect the area of concern.

A form for collecting the required ground runup information is given in Table II. The classes of aircraft and associated engine power settings are listed in the first column. The next four columns provide space for listing the number and duration of runups per active day for both daytime and nighttime periods. The number of runups should be taken as the average number occurring on normally active days. For example, if five to seven runups occur one day a week in a particular civil airport, the number to be reported in Table II is six, not one (for an average of one per day).

The final two columns are for expressing the ground runup information in terms of an average running time per hour, based on the time periods of primary concern. This figure is equal to the total running time per time period divided by the time span per period. Thus, for two civil turbojet engine runups at part power per day between 0700-2200, with an estimated duration of 10 minutes per runup, the daytime average total running time would be 2 times 10 divided by 15, or 1.3 minutes per hour.

For civil airports, operational information can usually be obtained by interrogation of the local airport authorities, FAA Tower Chief, airlines operations personnel, pilots, and study of published schedules. Detailed data on runway utilization are often not kept in routine records, but special studies are sometimes available to substantiate estimates. Flight paths can be verified by observation in affected areas.

TABLE II

SUGGESTED FORM FOR COLLECTING INFORMATION ON RUNUP OPERATIONS CONDUCTED AT EACH RUNUP AREA ON AN AIRPORT

Aircraft		Average Number of Runups on Active Days		Average Duration of Runup in Minutes		Average Total Running Time in Minutes Per Hour	
		0700 to 2200	2200 to 0700	0700 to 2200	2200 to 0700	0700 to 2200	2200 to 0700
CIVIL	Turbojets at "trim" (or "part") and takeoff power						
	Turbofans at 75% thrust to full takeoff power						
MILITARY	Runup Group 1*						
	Runup Group 2						
	Runup Group 3						
	B52H						
	C135B						

* Group classifications for individual military aircraft are given in Table A-2 of Appendix A.

Because the noise environmental information is being collected as an aid in locating and designing buildings which will usually be utilized for a number of years after construction, it is vital to devote time and care in developing predictions of the future noise environment. In predicting future aircraft traffic, one should be alert to possibilities which are outside or are in addition to straightforward extrapolation of current flight activities. One must consider such questions as: what are possibilities of a runway extension; the addition of parallel runways; the introduction of jet aircraft for short and medium range flights now handled by propeller aircraft; the liklihood of supersonic transport operations from the airport; the liklihood of handling military aircraft traffic; the liklihood of service by an additional airline; etc.

A questioning attitude is helpful in attempting to develop predictions other than those based upon the status quo. A personal visit to the site under consideration, observation of existing traffic, and careful study of maps of the airport and surrounding areas are vital steps in developing realistic projections of current flight activities.

Example:

Let us assume that we are interested in estimating perceived noise levels for an area adjacent to Runway 17 at a civil airport, for the daytime (0700-2200) period.

Step 1 then consists of determining the following information by inquiry and observation:

(a) Runway 17 is used primarily for takeoffs of turbofan and turbojet aircraft departing on intercontinental flights (trips over 2000 mi).

(b) The average total takeoff activity at the airport between 0700 and 2200 is 40 turbofans and 40 turbojets per day, or expressed in hourly activity rates, 2.7 operations per hour for either turbofan and turbojet aircraft.

(c) The runway utilization for Runway 17 is approximately 40%.

(d) The departure flight path is straight out along the runway heading.

Example:

Let us assume that investigation at a civil airport shows the following ground runups on normal active days:

(a) During daytime:

Three turbojet runups at "trim" power with average duration of ten minutes each;

Two turbojet runups at takeoff power with average duration of one minute each;

Two turbofan runups at part power with average duration of five minutes each.

(b) During nighttime:

Two turbofan runups at part power with an average duration of five minutes each.

(c) All runups occur at the same location on the airport with engine exhausts directed at a (true) heading of 020°.

From this information, we can complete the following table:

Aircraft		Average Number of Runups on Active Days		Average Duration of Runup in Minutes		Average Running Time Minutes/ Hour	
		0700 to 2200	2200 to 0700	0700 to 2200	2200 to 0700	0700 to 2200	2200 to 0700
CIVIL	Turbojets at "trim" (or "part") and takeoff power	3 2	0 0	10 1	0 0	2.1	0
	Turbofans at 75% thrust to full takeoff power	2	2	5	5	0.67	1.1

Step 2 - Determine Perceived Noise Levels For Aircraft Operations

The noise exposure expressed in terms of the perceived noise level for the land areas of concern may be established by direct measurement, or from generalized estimation methods such as Reference 1. Appendix A provides sets of perceived noise level contours covering takeoffs, landings, and ground runups of civil and military jet-powered aircraft, including takeoff and landing contours for selected civil helicopters. The selection of the appropriate contours for a particular problem is made by reference to Table A-3 in Appendix A. These contours permit the determination of noise levels in PNdB over a wide area underneath and off to the side of a flight path or around an aircraft operating on the ground.*

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* Reference 1 provides considerable helpful information concerning the construction and use of contours to determine noise levels and discusses several problems of interpretation that commonly arise.

Example:

From the operational information for aircraft takeoffs from Runway 17 collected in Step 1, and study of Table A-3 in Appendix A, we find that the appropriate noise contours to use are those of Contour Set 1B.

If the area of concern is located approximately 20,000 ft from the start of the takeoff roll and 2500 ft to the side of the path, use of Contours Set 1B with Table A-3 gives the following noise level estimates:

Turbojets	105 PNdB
Turbofans	100 PNdB

Example:

From the operational information for ground runups collected in Step 1, and study of Table A-3, we find that appropriate noise contours are Contour Sets 6 and 7.

If the area of concern is located approximately 3500 ft from the ground runup location, at an angle of 60° from the aircraft engine exhaust axis, the contour sets yield the following noise level estimates (to the nearest 5 PNdB):

Turbojets	85 PNdB
Turbofans	90 PNdB

Step 3 - Determine Composite Noise Ratings For Aircraft Noise

The Composite Noise Ratings for the different aircraft noises are obtained by adding to the perceived noise levels, determined in the previous step, corrections for operational factors that influence the reaction to aircraft noise. For takeoffs and landings, these factors are the frequency of operations and runway utilization. Correction numbers for these factors are given in Table III. For runup operations the operational factor considered most important is the

average hourly running time. The correction to be applied to the perceived noise levels for this factor is given in Table IV.

The Composite Noise Rating (CNR) for each flight operation is obtained simply by adding algebraically the total of the correction numbers determined from Tables III and IV to the perceived noise level in PNdB.

<u>Example:</u>
In Step 1 we determined that there were 2.7 takeoffs per hour of turbojets and 2.7 takeoffs per hour of turbofans during the 0700-2200 period on Runway 17. Further, the utilization of Runway 17 is about 40%. From Table III the activity correction is +5; the correction for runway utilization is 0. Therefore, the resulting CNR for each flight is:

(a) For turbojet takeoffs

CNR = 105 PNdB + (+5) = 110

(b) For turbofan takeoffs

CNR = 100 PNdB + (+5) = 105

<u>Example:</u>
In Step 1, we determined the average running time per hour for <u>ground runup operations</u> for turbojet and turbofan ground runup operations. For turbojets, the highest value (which occurred for daytime operation) was 2.1 minutes per hour, occurring during nighttime operations. From Table IV, the activity correction for turbojet runups is +5; for turbofan runups, the correction is 0. The resulting CNR's are:

(a) For turbojet runups

CNR = 85 PNdB + (+5) = 90

(b) For turbofan runups

CNR = 90 PNdB + (0) = 90

TABLE III

CORRECTIONS FOR NUMBER OF FLIGHT OPERATIONS (TAKEOFFS OR LANDINGS) AND RUNWAY UTILIZATION

Total Activity	
Number Per Hour	**Correction***
20 or greater	+15
7 - 19	+10
2 - 6.9	+ 5
0.7 - 1.9	0
0.2 - 0.69	- 5
less than 0.2	-10
Runway Utilization	
Runway Utilization	**Correction***
30% - 100%	0
10% - 29%	- 5
3% - 9%	-10
less than 3%	-15

TABLE IV

CORRECTION FOR DURATION OF GROUND AIRCRAFT ENGINE RUNUPS

Duration in Minutes Per Hour	Correction*
2 or greater**	+ 5
0.7 - 1.9	0
0.2 - 0.69	- 5
0.07 - 0.19	-10
less than 0.07	-15

* To be added to the perceived noise level.

** In Step 7, when determining specific building noise reduction requirements, consider runup noise as a continuous noise and base design requirements on steady-state noise criteria.

At this point in the analysis, a Composite Noise Rating will result for each takeoff and landing operation being considered, as well as for each runup operation. From the various CNRs one must be chosen to apply to the area in question for all flight operations, and one CNR to apply for all runup operations.

Since both takeoffs and landings have been divided into various categories and since the noise perceived at any one location will frequently be due to operations on several runways and/or flight paths, provisions must be made to recombine CNRs of comparable value. Only those CNRs within 3 units of the maximum CNR need be considered. If there are three or more categories fulfilling this requirement, one should add 5 units to the highest to determine the CNR for takeoffs. If there are less than three, the highest CNR applies.

Example:

In our study of takeoff operations from Runway 17, we found the CNRs for turbojet and turbofan operations were 110 and 105. According to the rules stated above, the CNR for takeoffs at the location in question is 110.

Had there been three or more CNR values for takeoffs between 107 and 110, the resultant CNR would have been 115.

In considering ground runup operations, a similar procedure is to be followed; if more than one runup operation was involved, the highest Composite Noise Rating for the several ground runup operations should be selected. If there are three or more CNRs within 3 units of the maximum CNR, 5 units should be added to the highest to determine the CNR applicable for all runup operations. This CNR, however, should not be combined with the CNR for flight operations.

Example:

In our study of ground runup operations, we found the CNR for turbojet and turbofan operations were each 90. Hence, the CNR value to use in future calculations should be 90.

Step 4 - Check Importance of Other Sources of Noise

At this point in the procedure, it is well to make a check to determine the relative importance and influence of other intermittent or continuous sources of noise. If these other sources of noise produce levels that are comparable with or exceed those produced by aircraft, land usage compatibility ratings, or building noise reduction requirements cannot be determined by considering only aircraft noise.

Information concerning the magnitude of other noise sources may be gathered from measurement and inspection, or estimated from accumulated engineering data.* To aid in estimating the effect of other noise sources, Figs. 2 and 3 and Table V provide estimates of several often-encountered types of intermittent and continuous noises.[14-19] Figure 2 shows typical outdoor perceived noise levels for various types of surface transportation, plotted as a function of distance from the noise source; similarily, Fig. 3 presents estimates of continuous background noise for freeway and busy urban street traffic. In addition, Table V lists the range of noise levels commonly experienced in various urban and suburban locations.

With this information we are now in a position to evaluate the relative importance of other noise with respect to aircraft noise. For intermittent noises, we should first compute a Composite Noise Rating (CNR) using Table VI. Note that computation of the CNR for intermittent noises is basically similar to that for aircraft flyover noise in that a correction factor based upon number of occurrences per hour is added to the perceived noise level to obtain

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* For comparison with the noise level information given in this report, noise information must be expressed in terms of the perceived noise level in PNdB. The perceived noise level can easily be calculated from octave or third-octave band noise measurements by the method described in Reference 2.

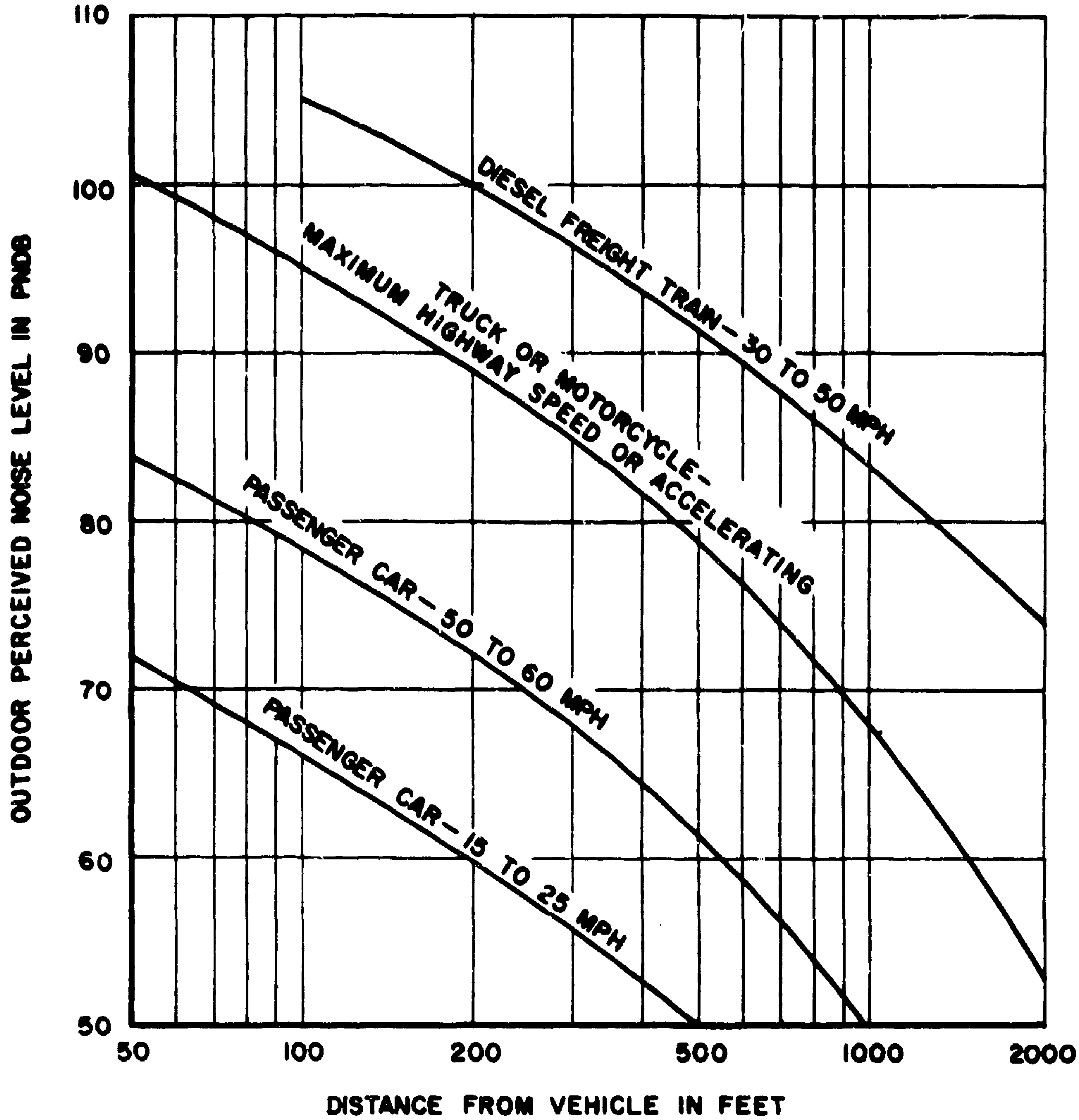

FIGURE 2. TYPICAL INTERMITTENT NOISE PRODUCED BY SURFACE TRANSPORTATION VEHICLES

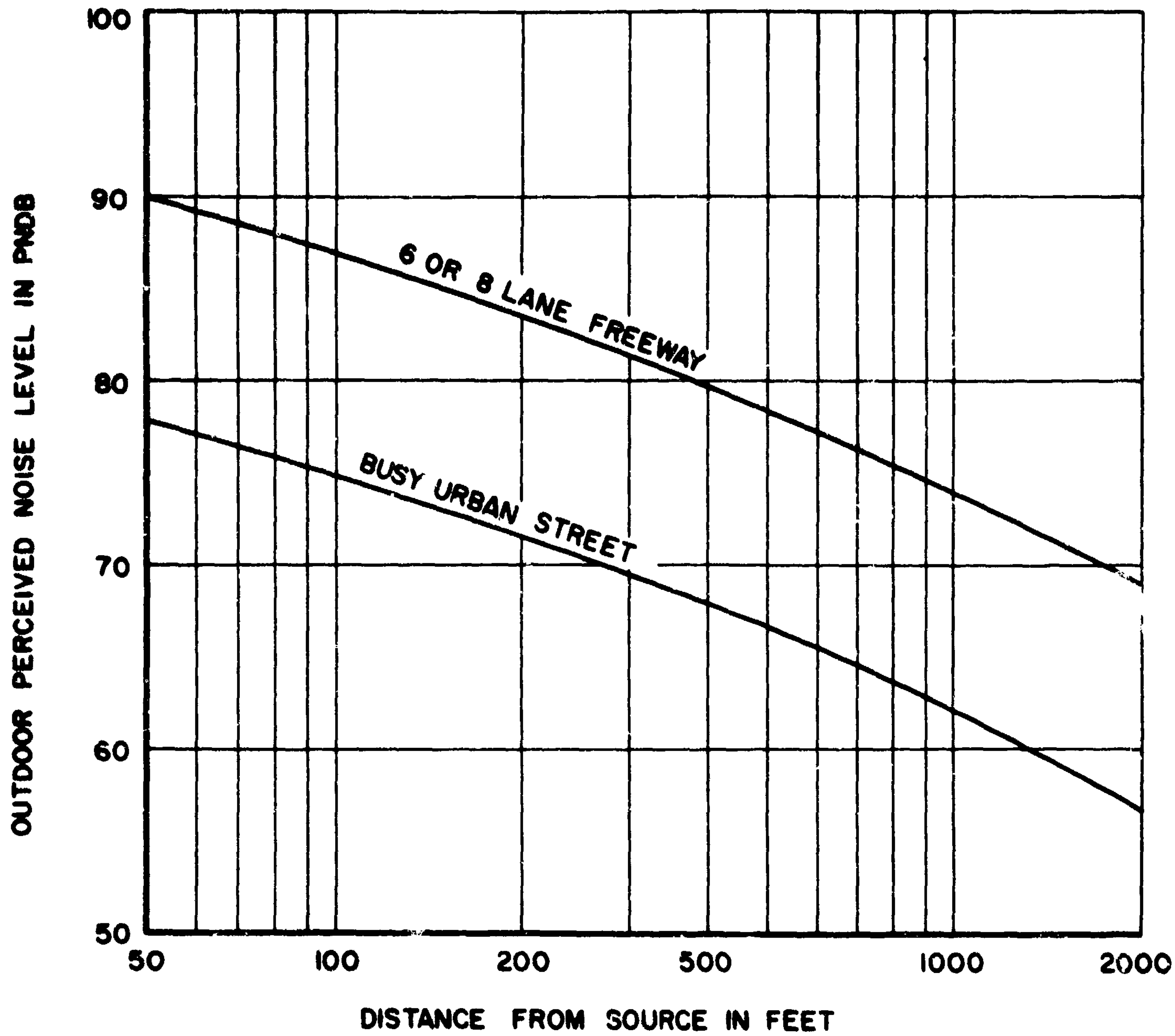

FIGURE 3. TYPICAL CONTINUOUS NOISE PRODUCED BY HEAVY SURFACE TRAFFIC

TABLE V

TYPICAL CONTINUOUS BACKGROUND NOISE LEVELS*

Source or Location	Perceived Noise Level in PNdB
"Downtown" commercial areas with heavy traffic	75 - 85
Industrial areas	60 - 80
Commercial areas, light traffic	60 - 70
Urban residential area (daytime)	55 - 65
Quiet suburban area (nighttime)	45 - 55

* See Figs. 2 and 3 for other background noise information.

TABLE VI

CORRECTION FOR NUMBER OF OCCURRENCES OF INTERMITTENT NOISE (OTHER THAN AIRCRAFT NOISE)

Number Per Hour	Correction*
20 or greater**	+15
7 - 19	+10
2 - 6.9	+ 5
0.7 - 1.9	0
0.2 - 0.69	- 5
less than 0.2	-10

* To be added to the perceived noise level.

** In Step 7, when determining specific building noise reduction requirements, consider the intermittent noise as continuous and base design requirements on steady-state noise criteria.

the CNR.* With intermittent noise sources expressed in terms of the Composite Noise Rating and continuous noise expressed in terms of the steady-state perceived noise level, we can compare the noises with the aircraft noise CNRs, computed in Step 3. Two major decisions are made at this point:

(a) To determine general land use compatibility in Step 5, we follow the rules:

(1) If the CNR for aircraft noise is 5 dB or more than any of the CNRs for other intermittent noise sources, or the perceived noise level for other steady-state noise sources, aircraft noise is the predominent noise source in determining general land use noise compatibility.

(2) If the CNR for other intermittent noise sources, or the perceived noise level for other steady-state noises, equals or exceeds the CNR for aircraft noises, the CNR values for aircraft noise may be used in the following step of the procedure with the understanding that other noise sources are likely to be of greater importance. Thus, only a tentative decision on general land use compatibility can be made on the basis of aircraft noise alone.

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* It is sometimes difficult to decide whether a noise should be classified as intermittent or continuous. Noise from distant street traffic, for example, can usually be classed as continuous since it is generally difficult to distinguish the rise and fall in noise produced by individual car passings. Close to a street with light automobile traffic, the noise would best be classed as intermittent, with an activity correction dependent upon an estimate of the number of auto passings per hour.

Classification of background noise as continuous will generally result in more stringent noise reduction requirements for the buildings.

(b) In computing detailed noise reduction requirements (in the procedure beginning with Step 6), the following rules apply:

(1) When comparing the Composite Noise Ratings produced by aircraft noise and by other intermittent noises, the highest CNR should be used to determine building noise reduction requirements.

(2) When comparing the CNR of aircraft noise with the steady-state perceived noise levels of other sources, the aircraft CNR should be used if it is greater than the steady-state level; if the steady-state perceived noise level values are equal to or are greater than the CNR values computed for aircraft noise, the steady-state noise levels should be used to compute noise reduction requirements, with noise level design criteria based upon steady-state (not aircraft) noise criteria.*

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* When noise other than from aircraft is dominant, appreciable error may be encountered in using the tables given in Step 6 and following steps. Such errors may arise because the values given in the various tables are based upon consideration of the typical frequency spectrum shapes of aircraft noise; other noises having drastically different spectrum shapes may require different values.

Fortunately, many commonly encountered background noises and the noise produced by many types of surface vehicles have spectrum shapes sufficiently similar to aircraft noise to permit use of the tables without introduction of large errors. Thus, the procedures and data following Step 5 can provide an adequate estimate of building requirements for many commonly encountered noises. However, a more detailed analysis of the noise environment is generally advisable when the noise from other sources exceeds noise from aircraft.

Example:

The area of interest, in our study of noise produced by takeoff operations from Runway 17, is located in an industrial area 300 ft from a street handling considerable truck traffic, with trucks accelerating after stopping at a traffic intersection. Observation shows a typical activity rate during daytime hours of 20 trucks per hour.

From Fig. 2, page 21, we estimate the intermittent truck noise as 85 PNdB. From Table VI, page 24, we obtain an activity correction of 15; the resulting CNR is:

CNR (truck noise) = 85 PNdB + (15) = 100

This CNR value of 100 is 10 dB less than the CNR value of 110 calculated in Step 3; hence aircraft flyovers are the predominant noise source.

Example:

The area studied with respect to aircraft runup noise is located 200 ft from a busy freeway. From Fig. 3, we estimate a continuous background noise level of 85 PNdB. This value is the same as our previously calculated Composite Noise Ratings for runup noise. Thus, since freeway noise is comparable with the runup noise, only a tentative decision on general land use compatibility can be made, without analyzing the freeway noise in more detail.

When computing detailed noise reduction requirements at this location in Step 7, the noise reduction requirements should be determined by comparison of the continuous perceived noise level of 85 PNdB (due to freeway noise) with steady-state noise criteria.

Step 5 - Determine General Land Usage Acceptability

With the values of Composite Noise Ratings determined in Step 3 (and checked for applicability in Step 4), we are now in a position to rate the general land usage compatibility with respect to aircraft noise. This rating is done by comparing the CNR values with those given in Table VII. In Table VII are shown four noise sensitivity zones, I, II, III, IV, with accompanying sets of CNR ratings (one set for flyover noise, and one for ground runup noise). The following nine columns show the compatibility of land usage for a number of major land use categories having different sensitivities to noise.

For most columns the ratings start, for the lowest noise compatibility zone, (or lowest CNR ratings), with the word "yes" indicating there should be no adverse effects from aircraft noise. Corresponding to the higher noise sensitivity zone, some of the columns have the word "no" printed. "No" indicates that unless extensive, and often expensive design precautions are taken, noise will likely constitute a severe interference to the land use. Between the "yes" and "no" response there is generally a range of CNR ratings where construction should be avoided unless a detailed analysis is made to determine specific building noise reduction requirements.

Table VII is based upon a consideration of the typical range of work tasks involved in the different land use categories. Although the primary concern is the effect of aircraft noise on speech communication, it is also based upon case history experience involving numerous aircraft noise problems at various military and civilian airports. Table VII assumes that the type of lightweight building construction contemplated for the different land uses is that which would normally be used when aircraft noise is of no concern. Thus, the land use compatibility ratings for schools assumes building construction involving single glazing in classrooms. Special noise control construction incorporating double glazing or elimination of windows entirely, etc., has not been considered.* Likewise for residential use, building noise reduction values for houses assume construction with movable sash single-pane windows.

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* Various modifications to building noise reduction due to changes in construction are considered in more detail in Step 9.

TABLE VII

LAND USE COMPATIBILITY CHART FOR AIRCRAFT NOISE

Noise Sensitivity Zone	Composite Noise Rating (CNR)		LAND USE COMPATIBILITY								
	Takeoffs and Landings	Ground Runups	Residential	Commercial	Hotel, Motel	Offices, Public Buildings	Schools, Hospitals Churches	Theaters, Auditoriums	Outdoor Amphi-Theaters, Theaters	Outdoor Recreational (Non-spectator)	Industrial
I	Less Than 90	Less Than 70	yes	yes	yes	yes	yes	Note (A)	Note (A)	yes	yes
II	90-100	70-80	yes	yes	yes	yes	Note (C)	Note (C)	no	yes	yes
III	100-115	80-95	Note (B)	yes	Note (C)	Note (C)	no	no	no	yes	yes
IV	Greater Than 115	Greater Than 95	no	Note (C)	no	no	no	no	no	yes	Note (C)

NOTE (A) - A detailed noise analysis by qualified personnel should be undertaken for all indoor or outdoor music auditoriums and all outdoor theaters.

(B) - Case history experience indicates that individuals in private residences may complain, perhaps vigorously. Concerted group action is possible. New single dwelling construction should generally be avoided. For high density dwellings (apartments) construction, Note (C) will apply.

(C) - Avoid construction unless a detailed analysis of noise reduction requirements is made and needed noise control features are included in building design.

The noise sensitivity zones should, of course, be used as guides to compatible land use planning, not as rigid geographic boundaries. Intelligent and careful interpretation is called for, taking into account possible influences of local terrain and inexactitudes in locating flight paths or in estimating future aircraft traffic trends.

<u>Example:</u>

With the CNR value of 110 for our industrial area located near the takeoff path from Runway 17, we see from Table VII that the noise environment is compatible for commercial and industrial uses; if we plan offices, public buildings, a hotel or motel, a detailed analysis of building noise reduction requirements should be made. The area is not satisfactory for construction of schools, hospitals, theaters or auditoriums.

For general consideration of land use compatibility in planning stages, Table VII should prove useful and quite complete. For a detailed examination of particular building requirements, the succeeding steps of the procedure should be followed.

Step 6 - Determine Activity Criteria for Aircraft Noise

After determining the outside noise environment, expressed in terms of the Composite Noise Ratings of Step 3, the next step in developing and determining building construction noise reduction requirements is to determine the appropriate noise criterion value. This step is essentially a two-part procedure. First comes selection of an appropriate steady-state noise criterion based upon acceptable levels for specific work activities or upon noise levels permitting a desired degree of ease of speech communication.

Table VIII shows typical steady-state noise criteria for a number of commonly encountered environments.[3,4]

In most offices and work spaces the most prevalent problem associated with intruding aircraft noise is one of speech interference and annoyance resulting from the disruption of

TABLE VIII

TYPICAL STEADY-STATE NOISE CRITERIA

Type of Space	Noise Criteria in PNdB*
Concert and Opera Halls	35 - 45
Broadcast and Recording Studios	35 - 45
Legitimate Theaters	40 - 50
Movie Theaters	45 - 55
Television Studios	40 - 50
Schoolrooms**	45 - 55
Churches**	40 - 50
Courtrooms**	45 - 55
Hospitals	45 - 55
Restaurants	55 - 65
Retail Stores	55 - 65
Supermarkets	60 - 70
Sports Coliseums (indoor)	55 - 70
Bowling Alleys, Gymnasiums	55 - 65
Hotel Rooms	45 - 55
Hotel Lobbies	60 - 70
Libraries	45 - 55

* Values adapted from tables of References 3 and 4; see Appendix C for details of conversion of reference criteria to values of perceived noise level.

** No speech amplification system.

speech communication. Tables IX and X provide guidance in selecting perceived noise levels acceptable for different speech communication purposes.*

Table IX shows the relation between perceived noise levels and the communication conditions for a degree of intelligibility that is marginal with conventional vocabulary and good with selected vocabulary, for speakers facing each other. Table X presents perceived noise level criteria for various office environments. From Tables IX and X it should be possible to select noise criteria appropriate for most any type of work activity involving varying degrees of speech communication.

After selection of steady-state criteria, the next step involves the selection and addition of two adjustment factors which account for the transient and intermittent nature of most aircraft noises. Selection of these factors is based upon two judgments regarding speech communication (or other particular noise-dependent requirements of the work activity) within the space. The first adjustment factor calls for an assessment of the value of speech communication to the work activity under consideration (or alternatively, for activities where speech communication is not the critical noise consideration, an assessment of the importance of freedom from intermittent noise intrusions). The adjust values for this judgment are shown in Table XI.

The second adjustment factor is based upon a consideration of the relative frequency with which speech communication will be used within the space (or, alternatively, an assessment of the difficulty, or inconvenience, of repeating signals which may be masked by the intruding aircraft noise). Adjustment values for this are shown in Table XII.

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* Tables IX and X have been adapted from tables which were originally stated in terms of the speech interference level (SIL), defined as the average of the octave band sound pressure levels in the three octave frequency bands, 600-1200, 1200-2400, 2400-4800 cycles per second. The perceived noise level values are based upon the relationship between perceived noise level and SIL for aircraft noises heard inside buildings of typical lightweight commercial construction. (See Appendix C.)

TABLE IX

SPEECH COMMUNICATION CRITERIA FOR CONTINUOUS NOISE*

Relation between continuous noise levels and the communication conditions, for a degree of intelligibility that is marginal with conventional vocabulary, and good with selected vocabulary, speakers facing each other.

Perceived Noise Level Range	Distance Limits for Reliable Conversing	Nature of Possible Speech Communication	Radio and Telephone Use
45 - 55	Normal Voice at 15 to 30 ft Raised voice at 25 to 50 ft	Continuous communication	Satisfactory
55 - 65	Normal voice at 7 to 14 ft Raised voice at 15 to 30 ft	Continuous communication	Satisfactory
65 - 75	Normal voice at 2 to 5 ft Raised voice at 4 to 8 ft Very loud voice at 8 to 16 ft	Continuous communication	Slightly difficult
75 - 85	Raised voice at 1 to 2 ft Very loud voice at 2 to 5 ft Shouting at 5 to 10 ft	Intermittent communication	Difficult
85 - 100	Very loud voice at 1 ft Shouting at 2 to 3 ft	Minimal communication (danger signals: restricted vocabulary desirable)	Unsatisfactory

* Applies to noise having frequency spectrum shapes similar to aircraft noise.

TABLE X

CONTINUOUS NOISE CRITERIA FOR OFFICES

Perceived Noise Level Range	Communication Environment	Typical Applications
40 - 50	Very quiet office; telephone use satisfactory; suitable for large conferences.	Executive offices and conference rooms for 50 people.
50 - 55	"Quiet" office; satisfactory for conferences at a 15 ft table; normal voice 10 to 30 ft; telephone use satisfactory.	Private or semiprivate offices, reception rooms and small conference rooms for 20 people.
55 - 60	Satisfactory for conferences at a 6 to 8 ft table; telephone use satisfactory; normal voice 6 to 12 ft.	Medium-sized offices and industrial business offices.
60 - 70	Satisfactory for conferences at a 4 to 5 ft table; telephone use occasionally slightly difficult; normal voice 3 to 6 ft; raised voice 6 to 12 ft.	Large engineering and drafting rooms, etc.
70 - 75	Unsatisfactory for conferences of more than two or three people; telephone use slightly difficult; normal voice 1 to 2 ft; raised voice 3 to 6 ft.	Secretarial areas (typing), accounting areas (business machines), blueprint rooms, etc.
Above 75	"Very noisy"; office environment unsatisfactory; telephone use difficult.	Not recommended for any type of office.

TABLE XI

ADJUSTMENT TO CONTINUOUS NOISE CRITERIA TO ACCOUNT FOR VALUE OF SPEECH COMMUNICATION*

Speech Value Judgment	Adjustment**
Critical	- 5 PNdB
Vital	0
Important	+ 5
Routine	+10

TABLE XII

ADJUSTMENT TO CONTINUOUS NOISE CRITERIA TO ACCOUNT FOR FREQUENCY OF USAGE OF SPEECH COMMUNICATION***

Frequency of Usage	Adjustment**
Continuous	- 5
Frequent	0
Infrequent	+ 5
Rarely or Never	+10

* Or, to account for the value of maintaining freedom from intermittent noise intrusions.

** To be added to the continuous noise criterion.

*** Or, to account for the difficulty (or inconvenience) in repeating signals masked by the aircraft noise.

Example:

Consider a work space where frequent voice communication will be necessary. Normally, for continuous noise, we would select a criterion value which would enable the speakers to communicate easily at a normal voice level. Thus, from Table X we select a value of 60 PNdB. If the value of the speech communication to the activity in the space is important, but not vital, Table XI shows that an adjustment of +5 PNdB should be used. Then, from Table XII, we obtain an adjustment of 0 dB accounting for frequent need for speech communication. The total adjustment to the continuous noise criterion is the sum, +5 + (0) = +5. Thus, the aircraft noise criterion for this particular space would be 60 + 5 or 65 PNdB.

There are a number of activities where freedom from noise intrusion cannot be judged solely upon the basis of speech communication. In such cases, Tables XI and XII can be interpreted in terms of the importance of having freedom from transient noise intrusions, and in terms of relative difficulty of repeating signals masked by transient noise intrusion.

Example:

In a concert hall, where speech communication is, in itself, a relatively minor consideration, we might well judge the importance of freedom from noise intrusion to be critical. Thus from Table XI we would provide an adjustment of -5 PNdB to the steady-state criterion.

We may also interpret Table XII in terms of the ability to repeat a music signal masked by noise. Thus, we would likely judge it impossible without severe disruption of the concert continuity to repeat a signal masked by noise, hence we would select an adjustment of -5 from Table XII. Thus, the total corrections to the continuous criterion for the concert hall would be -10 PNdB.

While a correction of -10 PNdB appears high in this example, since it apparently makes the criterion for transient noise more severe than the steady-state criterion, the values given in Tables XI and XII help to adjust aircraft criterion values for the relatively large variation in maximum noise levels observed at positions underneath aircraft flight paths during flyovers of a large number of aircraft. Thus, the -10 PNdB adjustment compensates for the fact that small percentages of the aircraft flyovers will produce noise which will exceed the estimated flyover noise levels by amounts of 5 to 10 PNdB.

For convenience in selecting an aircraft noise criterion, Table XIII shows some criteria for aircraft flyover noise, based upon the use of Tables VIII, X, XI, and XII. One may use these values as assembled in Table XIII or one can derive individual criteria for specific applications as just described.

In schools, for example, not all classrooms or spaces within a school building may demand the same steady-state noise levels, nor the same noise adjustment factors for flyover noise. The aircraft noise criterion given in Table XIII can then be interpreted as a guide with modifications for specific room applications obtained by using Tables IX, X, XI, and XII.

Step 7 - Determine the Needed Building Noise Reduction

The building noise reduction requirements may now be determined on the basis of the Composite Noise Rating for aircraft noise (determined from Step 3) and the aircraft noise level criterion (determined from Step 6). The difference in values is the needed building noise reduction.* This noise reduction can be achieved by the building construction (walls, roof, windows, etc.), plus effects of particular room or building orientation with respect to the aircraft flight paths.

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* In this report, the building noise reduction will be expressed as a difference in perceived noise levels. Appendix B discusses some of the approximations involved in expressing noise reduction in terms of a single number.

TABLE XIII

TYPICAL ROOM CRITERIA FOR AIRCRAFT NOISE

Type of Space	Steady-State Noise Criterion in PNdB	Speech Value Adjustment	Speech Frequency Adjustment	Aircraft Noise Criterion in PNdB
Concert and Opera Halls	40	-5	-5	30
Legitimate Theaters	45	0	-5	40
Movie Theaters	50	5	0	55
School Rooms	50	5	0	55
Churches	45	5	0	50
Hospital Rooms	50	5	0	55
Restaurants	60	5	5	70
Retail Stores	60	5	5	70
Supermarkets	65	10	5	80
Sports Coliseum (Indoors)	65	5	5	75
Hotel Rooms	50	5	5	60
Outdoor Amphitheaters	50	0	0	50
Offices - Executive	50	0	0	50
- Secretarial (mostly typing)	65	10	5	80
- Drafting	60	10	5	75

Example:

For the area located near the takeoff paths from Runway 17, we wish to locate an industrial building that will include some engineering drafting activities. From Table XIII, we select an aircraft noise criterion for such drafting space of 75 PNdB. In Step 3, we determined a CNR of 110 due to flyover noise. The needed building noise reduction for aircraft noise is 110 minus 75, or 35 PNdB.

Step 8 - Determine Room/Building Shielding Contribution to Noise Reduction

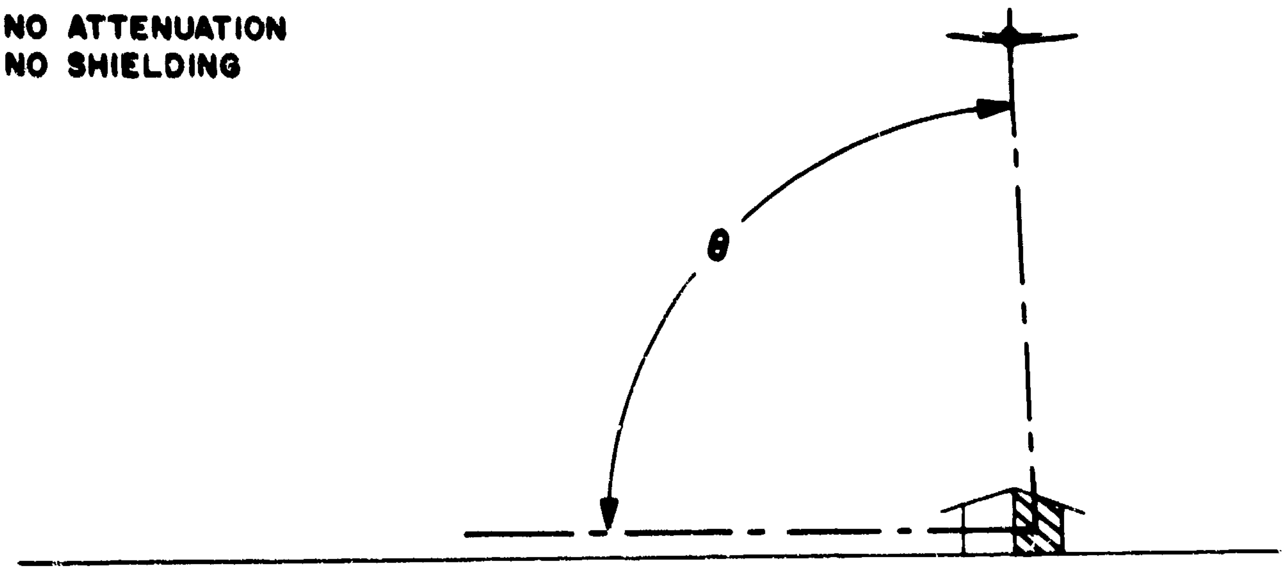
The estimates of needed building noise reduction values obtained in Step 7 are based upon an assumption that a sizeable percentage of the room (or building) walls and roof are directly exposed to the flyover noise levels estimated in Step 3. In practice, this may not be true because of the particular orientation of the building with respect to the aircraft flight path, or the location of a particular room within a building. In such cases the noise reduction estimates based on the previous assumption are too conservative, and interior noise levels will be less than estimated.

When noise from an aircraft in flight travels nearly parallel to the surface of the ground to reach the observer, a noise attenuation correction is needed when using the Appendix A takeoff or landing contours for estimating perceived noise levels in Step 3. This correction accounts for the typically greater attenuation of sound with distance for ground-to-ground propagation of sound compared to the air-to-air attenuation incorporated in the landing or takeoff noise contours of Appendix A.

The cases in which attenuation and shielding factors are likely to be important can be summarized with reference to Fig. 4 which shows three positions of an aircraft flight path with respect to a room within a building. In Fig. 4-A, the aircraft is flying directly over the building, with the roof and walls directly exposed to the aircraft noise. In Fig. 4-B

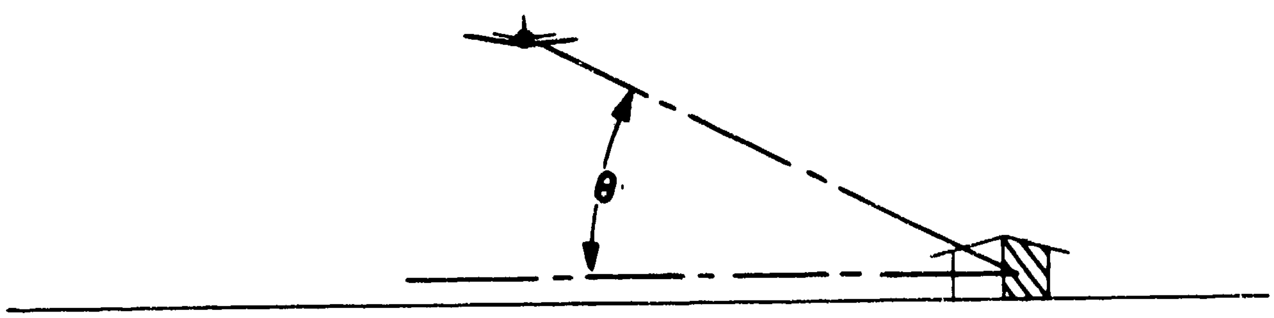
A. AIRCRAFT OVERHEAD ($60° < \theta \leq 90°$)

NO ATTENUATION
NO SHIELDING



B. AIRCRAFT TO ONE SIDE ($15° < \theta < 60°$)

NO ATTENUATION CORRECTION
SHIELDING UNLIKELY



C. AIRCRAFT NEARLY HORIZONTAL ($\theta < 15°$)

ATTENUATION CORRECTION—SEE TABLE 14
SHIELDING—SEE FIGURE 5

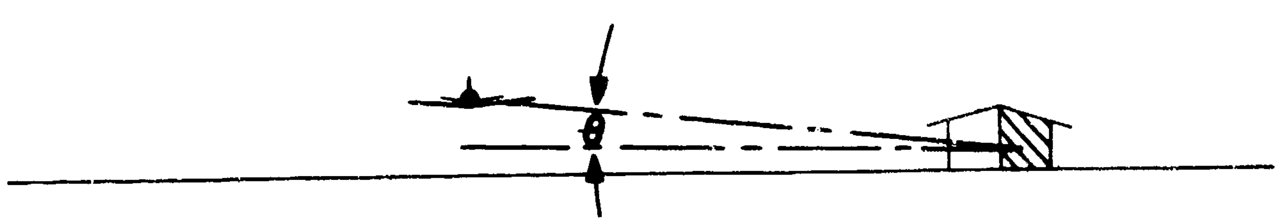


FIGURE 4. ILLUSTRATION OF SHIELDING AND ATTENUATION DEPENDENCE UPON AIRCRAFT FLIGHT PATH

the aircraft is flying overhead but well off to one side of the building. There is some shielding of the room wall; however, the magnitude of the shielding is not likely to be large.*

In Fig. 4-C the aircraft is shown flying past the building at less than a 15° horizontal angle. In this case there may be considerable reduction of the noise due to the greater attenuation of sound usually observed for sound waves traveling nearly parallel and close to the ground. In addition, there may be further reduction of noise levels due to the shielding provided by the building.

Table XIV summarizes the situations indicated in Fig. 4 and shows when correction factors due to attenuation or shielding should be considered. The sound attenuation corrections are shown in Table XV. These values should be used when the vertical angle between aircraft and ground is less than 15°, or where there are a number of large intervening objects between the aircraft and the building so that line-of-sight conditions do not apply.**

Some of the situations where shielding will be beneficial in reducing the exterior noise levels are illustrated in Fig. 5. This figure shows some of the commonly encountered conditions where significant noise shielding, amounting to the order of 10 PNdB or more can be achieved. Conditions are shown for both ground runups and for aircraft takeoffs or landings.

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* Because of the relatively large ratio of building dimensions to the sound wavelength in the audible frequency range, distinct shadow zones are less likely to be encountered than in the commonly experienced optical situation. Thus, even when building and room walls are not directly exposed to the sound waves, the sound waves will bend about intervening objects and obstacles so that sound levels in areas not within direct line of sight of the noise source may not be much less than the levels in areas directly exposed to the flyover noise.

** This correction would not be used, of course, if the outside noise level values were based upon direct measurement, instead of estimates from Appendix A.

TABLE XIV

CONSIDERATION OF OVERHEAD ORIENTATION OF AIRCRAFT FLIGHT PATHS

Flyover Direction	Angle from Above Horizontal Plane*	Sound Attenuation Correction	Shielding Benefit	Relative Ranking of Importance in Achieving Needed Noise Reduction		
				Sidewalls		Roof
				Facing Towards Aircraft	Facing Away From Aircraft	
Overhead	60° to 90°	None	None	1	1	1
To one side	15° to 60°	None	Unlikely	1	2	1
To one side	Less than 15°	Yes, See Table XV	Yes, See Fig. 5	1	3	2

* See Fig. 4 for sketch.

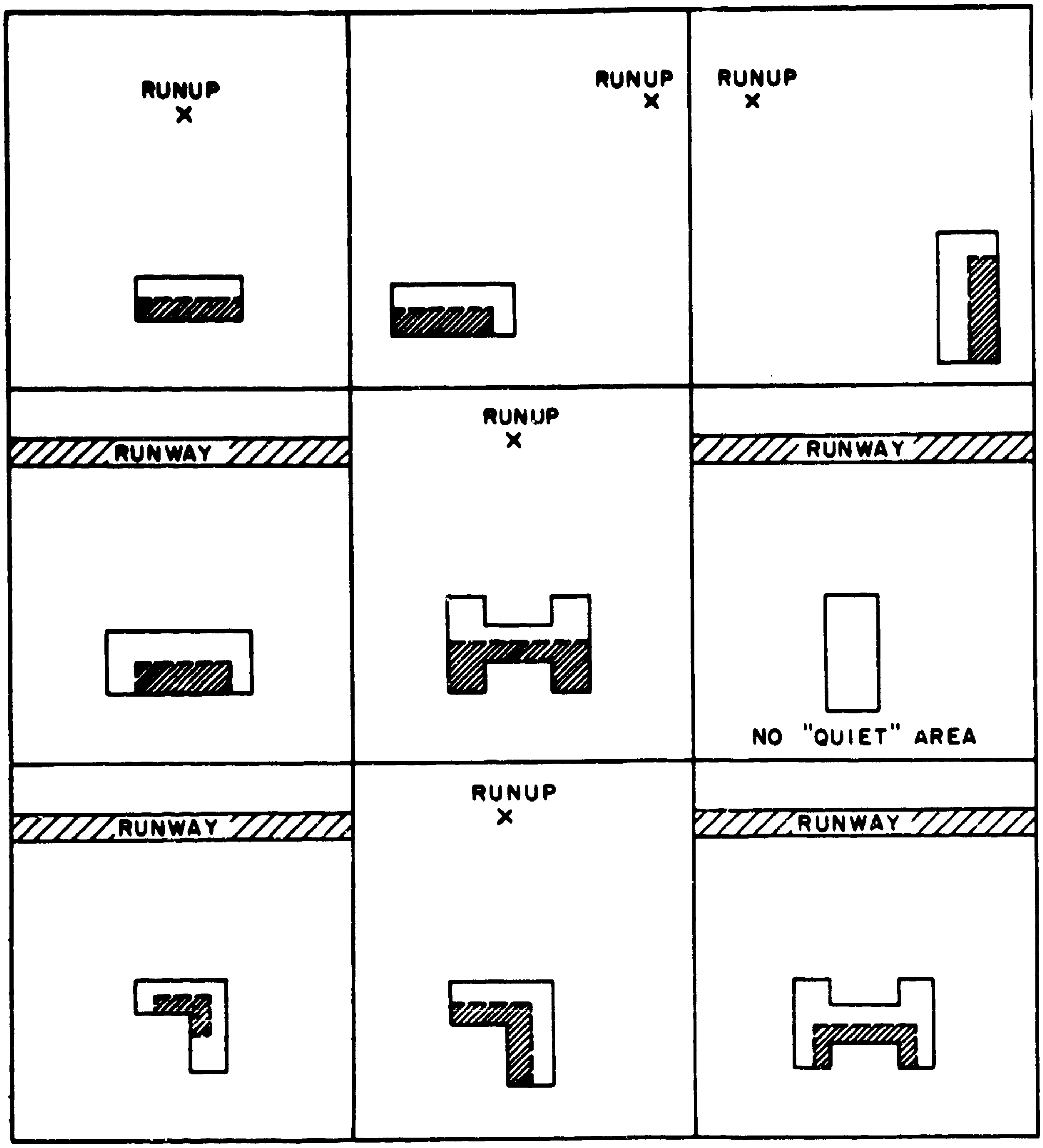
TABLE XV

GROUND-TO-GROUND ATTENUATION CORRECTIONS

Horizontal Distance From Flight Path Centerline to Building	Correction*
less than 500 ft	0
500 - 1500 ft	- 5
1500 - 6000 ft	-10
greater than 6000 ft	-15

* To be added to the perceived noise level values obtained from flyover contours.

PERCEIVED NOISE LEVELS IN SHADED AREAS WILL BE 10 PNDB LESS THAN THOSE IN UNSHADED AREAS.



NOTE: ALL BUILDINGS SHOWN ARE ASSUMED TO HAVE NO MORE THAN ONE ROW OF ROOMS ALONG EACH WALL.

FIGURE 5. LOCATION OF "NOISY" AND "QUIET" AREAS IN A BUILDING.

Example:

Again considering the area located near the takeoff path from Runway 17, observation shows that the jet transport aircraft have reached an altitude of 800 ft or greater before flying past our ground position of interest.* Our area of concern is located 2500 ft to the side of the takeoff path; therefore the angle of elevation (θ in Fig. 4) is about 18°. Thus, the relation of aircraft to ground position resembles that of Fig. 4-B. From Table XIV we see that there are no sound attenuation or shielding corrections to be applied.

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* Altitudes may be estimated by reference to aircraft takeoff profile charts (see, for example, the generalized profiles in Attachment 3 of ref. 1), altimeter readings furnished by the crew of the aircraft, or by direct observation. Observation by means of photographs taken by an observer on the ground, can furnish quite accurate measurements of the slant distance between observer and aircraft. Aircraft should be photographed as they pass closest to the observer. From comparison of an actual aircraft dimension with the size of the photo image (using care not to select a foreshortened dimension of the photograph) and knowledge of the cameral focal length, the slant distance, s, can be calculated:

$$s = \frac{\text{aircraft dimension}}{\text{photo image size}} \cdot \frac{\text{Camera focal length}}{1}$$

For angles of elevation (θ) of 75° or greater, the slant distance, s, provides an adequate estimate of the altitude. For smaller angles of elevation, the altitude can be estimated from the slant distance and an estimate of the angle of elevation.

Altitude = $s \sin \theta$

Step 9 - Establish Noise Reduction Values Due to Building Construction

Table XVI provides a list of the noise reduction values to be used for different types of building construction. Two sets of values are given in the right hand column. The first set is to be used for noise produced by turbojet, turbofan, and propeller powered aircraft during takeoff, by propeller aircraft during landing, and by turbojet and turbofan ground runups. The second set is to be used for turbojet and turbofan aircraft during landing operations.

The table starts with conventional lightweight construction (as exemplified by wood frame with various types of veneers, or lightweight concrete block construction) with three values shown corresponding to windows open, windows closed, and no windows. Following the lightweight wall construction entry, noise reduction values for 1/8" and 1/4" glass windows and for heavier wall and roof construction weighing from 20 to over 80 lbs per sq ft are given.*

TABLE XVI

* For wall construction for which the Sound Transmission Class (STC) is known, in accordance with ASTM E90-61T (Tentative Recommended Practice for Laboratory Measurement of Airborne Sound Transmission Loss of Building Floors and Walls), noise reduction values in PNdB may be conservatively estimated by taking the STC, expressed in decibels (dB), and subtracting 10 dB. This value yields a conservative value of the wall noise reduction for turbojet and turbofan transport takeoffs and propeller aircraft takeoffs and landings. When considering noise reduction requirements for buildings near landing paths of turbojet or turbofan transport aircraft, use the STC value and subtract 5 dB.

TABLE XVI

BUILDING CONSTRUCTION NOISE REDUCTION VALUES IN PNdB

Type of Construction	TYPE OF FLIGHT OPERATION: Turbojet and Turbofan Takeoffs and Ground Runups; Propeller Aircraft Takeoffs and Landings	Turbojet and Turbofan Landings
Conventional lightweight - windows open	15	20
Conventional lightweight - windows closed	25	30
Conventional lightweight - no windows, or 1/4" glass windows sealed in place	30	35
1/8" glass windows, sealed in place	20	25
1/4" glass windows, sealed in place	25	30
Walls and roof - weighing 20 to 40 lbs/sq ft, no windows	35	40
Walls and roof - weighing 40 to 80 lbs/sq ft, no windows	40	45
Heavy walls and roof - weighing over 80 lbs/sq ft, no windows	45	50

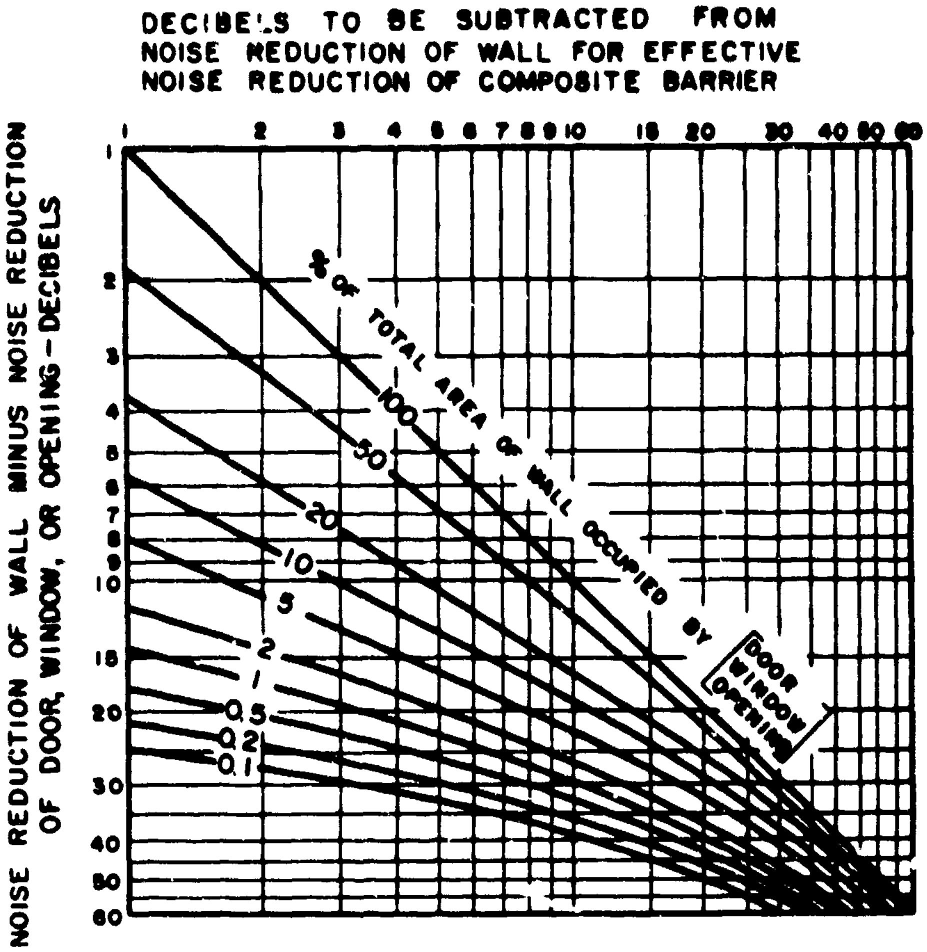
The noise reduction for composite construction, having different types of walls or roofs which vary in weight may be estimated from Fig. 6.

> <u>Example</u>:
>
> For the area near the takeoff path of Runway 17, we are considering construction of a single story concrete block building to house the engineering drafting offices. The building will be air conditioned, with fixed single glazing. Inspection of Table XVI shows that we might expect to achieve 30 PNdB noise reduction with this type of construction.

<u>Step 10 - Compare Estimated Building Reduction With Needed Noise Reduction</u>

The value of noise reduction obtained in Step 9 above may now be compared with the needed noise reduction previously determined in Step 7. If the estimated building reduction equals or exceeds the needed noise reduction, building construction should be adequate with respect to aircraft noise. If the estimated noise reduction value falls below the needed noise reduction value, a potentially serious noise problem may exist, with a definite possibility that noise from aircraft operations may seriously interfere with the planned work activities. In such cases, previous steps in the procedure should be reviewed for possibilities of introducing changes which will reduce the noise levels.

Where alternate building locations can be considered, studies of the noise contours of Reference 1 may indicate other locations exposed to lower noise levels. Where shielding may be possible, study of Fig. 5 may suggest changes in building shape or room location which will reduce the noise level in critical work areas. Review of room locations within a building may indicate ways in which the most noise sensitive work areas may be shifted so that wall or roof surfaces will not be directly exposed to aircraft noise. If such changes in room or building orientation are not feasible, Table XVI and Fig. 6 can be reviewed to determine the most economical ways in improving noise reduction by changes in building wall or roof surfaces.



EXAMPLE OF USE OF CHART:

8" DENSE CONCRETE BLOCK WALL (70 LBS/SQ. FT., 40 PNDB NOISE REDUCTION) WITH 1/8" FIXED-IN-PLACE WINDOWS (20 PNDB NOISE REDUCTION) OVER 5% OF WALL AREA HAS A COMPOSITE NOISE REDUCTION OF 32 PNDB. (PNDB VALUES OBTAINED FROM TABLE XVI)

FIGURE 6. CHART FOR DETERMINING NOISE REDUCTION OF COMPOSITE WALL STRUCTURES.

Example:

The total estimated noise reduction for our industrial building is 30 PNdB, the sum of the values obtained in Steps 8 and 9. This value equals the needed noise reduction obtained in Step 7, and no noise interference should occur.

If we had not been planning on air conditioning for the building, and were planning operable sash windows, our estimated noise reduction would drop (by Table XVI) from 30 to 25 PNdB (or 15 PNdB with windows open). Comparison of this value with the 30 PNdB needed noise reduction of Step 7 would indicate inadequate acoustic performance, introducing definite possibility that noise from the aircraft take-offs from Runway 17 would interfere with the work activities inside the building.

Review of Steps 1 Through 10

As an aid in applying the procedures, Fig. 7, like Fig. 1, lists each step in the general and detailed procedures. In addition, Fig. 7 lists the appropriate tables and figures which may be applicable in each step.

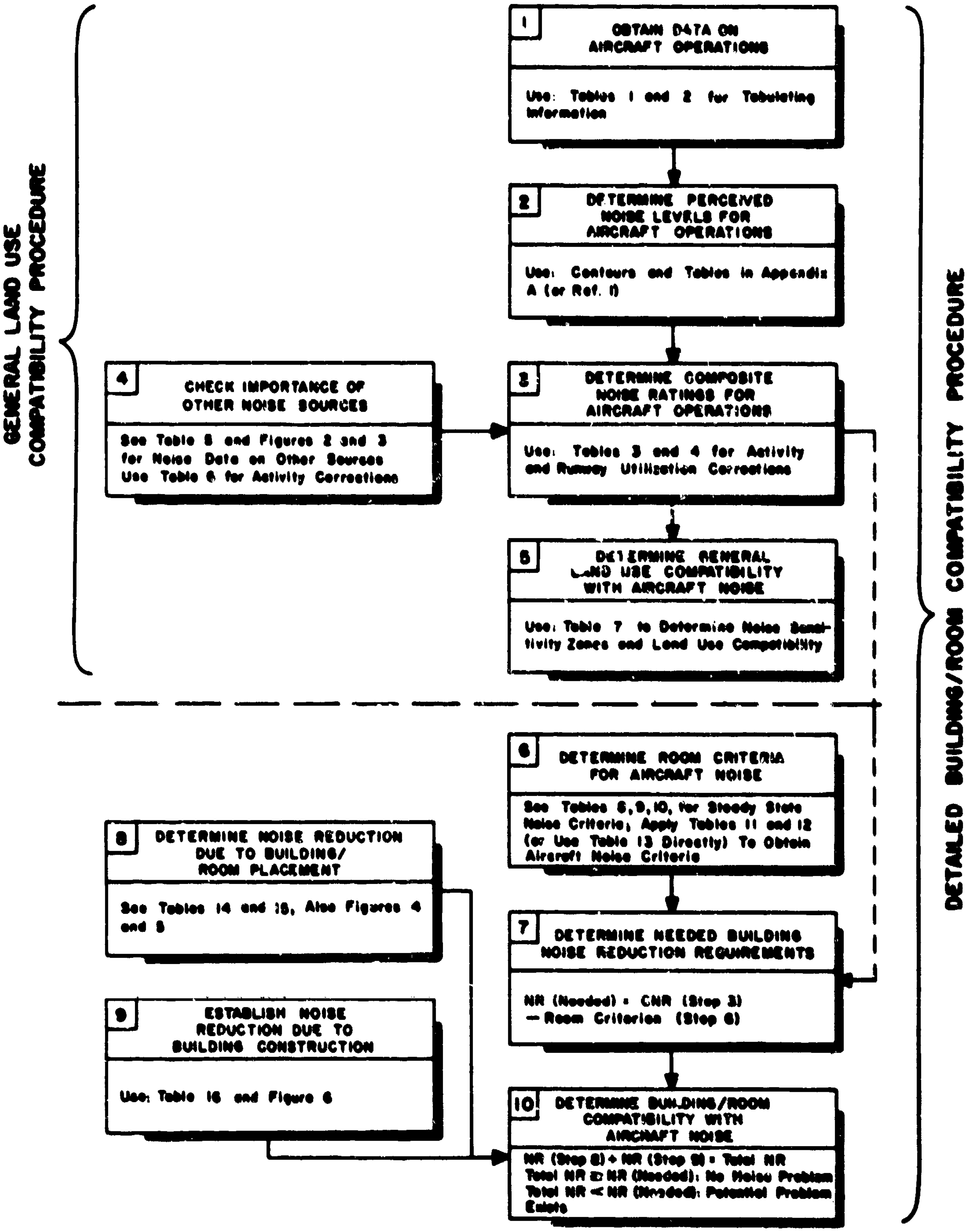


FIGURE 7. STEPS IN PROCEDURES FOR EVALUATING LAND USE COMPATIBILITY WITH AIRCRAFT NOISE

IV. EXAMPLES

In this section three examples illustrate the application of the procedures to different land use and building design situations. The first two examples show the application of the procedures in evaluating details of building arrangement and construction. The third example illustrates the use of pr(edures in developing and interpreting the noise sensitiv- it: zones.

All three examples are based upon the same case of aircraft operations from an airport having a single runway. A simple set of aircraft operations has been used in the examples to avoid details of contour construction and determination of perceived noise levels that are fully explained and illustrated in Reference 1.

Consider an airport with landings and takeoffs on Runway 8-26 as shown in Fig. 8. From interviews and field inspection, we prepare Table XVII showing estimates of aircraft activities for a period of five years hence. For simplicity, only jet aircraft operations are considered.

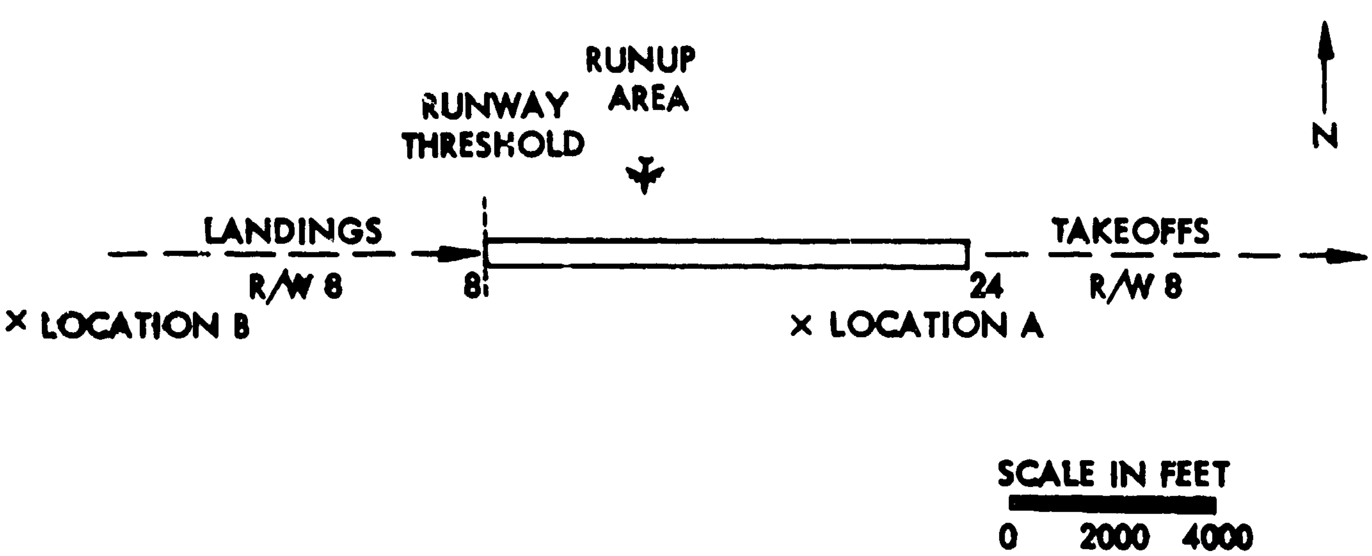


FIGURE 8. SKETCH OF HYPOTHETICAL AIRPORT USED IN EXAMPLES SHOWING PREDOMINANT FLIGHT PATHS

TABLE XVII

FLIGHT AND GROUND RUNUP ACTIVITY FOR HYPOTHETICAL AIRPORT OF FIGURE 8

AIRCRAFT TYPE	AVERAGE NO. OF MOVEMENTS		AVERAGE NO. OF MOVEMENTS PER HOUR		PERCENT RUNWAY UTILIZATION	
	0700 to 2200	2200 to 0700	0700 to 2200	2200 to 0700	8	26
TAKEOFFS						
Turbojets-Trips under 2000 mi	20		1.3	0.67	98	2
Turbojets-Trips over 2000 mi	5	2	0.33	0.22	98	2
Turbofans-Trips under 2000 mi	25	8	1.7	0.89	98	2
Turbofans-Trips over 2000 mi	10	3	0.67	0.33	98	2
LANDINGS						
Turbojets and Turbofans	60	19	4.0	2.1	95	5

AIRCRAFT/ENGINE	AVERAGE NO. OF RUNUPS		AVERAGE DURATION OF RUNUPS IN MINUTES		AVERAGE TOTAL RUNNING TIME IN MINUTES/HOUR	
	0700 to 2200	2200 to 0700	0700 to 2200	2200 to 0700	0700 to 2200	2200 to 0700
Turbojets	2	0	5	0	0.67	0
Turbofans	4	2	5	5	1.3	1.1

EXAMPLE 1 - Building Noise Reduction Requirements for a Small Factory Located Near the Airport Runway

Location A in Fig. 8 (approximately 6000 ft from the start of Runway 8, 1400 ft south of the runway centerline) is being considered for construction of a small factory comprising a machine shop, shipping and receiving areas, secretarial and drafting spaces, executive offices and conference rooms. Our first step in the analysis is to compile an estimate of the noise environment for this location utilizing the information in the above tables and the noise level information given in Appendix A.

From inspection of Fig. 8 we decide that we need consider as significant only the noise generated by takeoffs from Runways 8 and 26. We will consider only daytime operations since the factory will not normally operate during late evening or early morning hours.

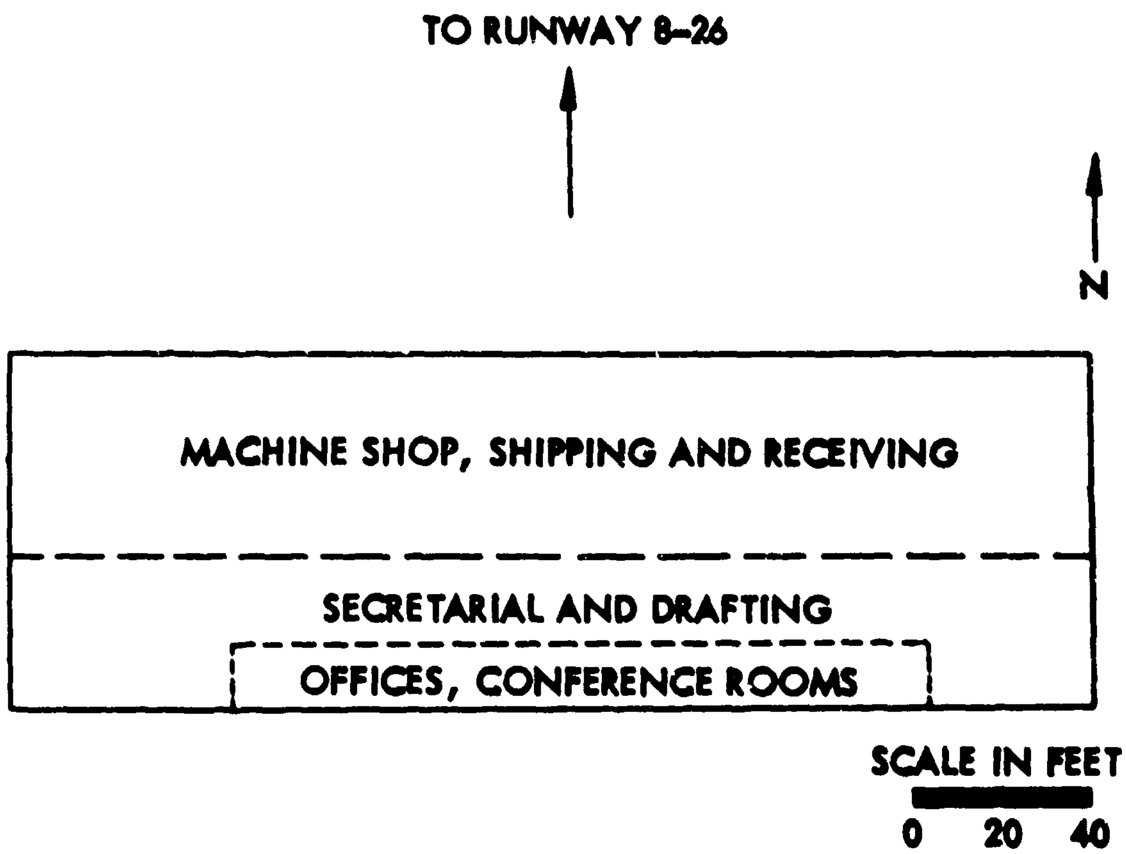
From the perceived noise level contours of Appendix A, we can compile the following table of noise levels.

AIRCRAFT TYPE	R/W	Perceived Noise Level* PNdB	Activity Cor.	R/W Util Cor.	CNR
Turbojet-Trips Under 2000 mi	8	114	-0	0	114
Turbojet-Trips Over 2000 mi	8	114	-5	0	109
Turbofan-Trips Under 2000 mi	8	109	0	0	109
Turbofan-Trips Over 2000 mi	8	109	-5	0	104
Turbojet-Trips Under 2000 mi	26	100	0	-15	85
Turbojet-Trips Over 2000 mi	26	100	-5	-15	80
Turbofan-Trips Under 2000 mi	26	103	0	-15	88
Turbofan-Trips Over 2000 mi	26	103	-5	-15	83

* For Runway 8 noise levels were determined from Contour Sets 1A and 1B. For Runway 26, where aircraft would not be airborne until well past the factory, the ground runup contours, (Contour Sets 6 and 7) were consulted, following the procedure outlined in Example 4 of Reference 1.

Applying the activity and runway utilization corrections from Table III, we compute the CNR values listed in the last column of the table. From the table we can see that the maximum CNR is 114. Since there are no other noise sources of importance, we can then compare the value of 114 with our land use compatibility chart, Table VI. Although the noise environment falls near the upper limit of Noise Sensitivity Zone 2 which is satisfactory for industrial use, a more detailed analysis is warranted since the industrial facilities include several types of office spaces having quite different sensitivities to noise.

The sketch below illustrates the initial layout of the industrial building with the machine shop, shipping and receiving areas located closest to the airport runway.



The facility is to be a single story building of concrete block construction with metal decking and builtup roof. The office spaces have fixed windows and are to be air conditioned.

The machine shop is to have operable sash windows which will normally be closed since forced air ventilation will be provided. Only the north and south walls will contain windows.

Table XVIII is a work sheet for computations of Steps 6 through 10 of the procedures.

TABLE XVIII

PROCEDURE STEPS FOR EXAMPLE 1

	Step 6				Step 7	Step 8		Step 9	Step 10	
Work Space	Continuous Noise Criteria	Adjustments For Value	Adjustments For Freq. of Usage	Aircraft Noise Criteria	Needed Noise Reduction (NR)	Air Atten. Cor.	Shield. Cor.	Build Const. NR	Total NR	Compar-ison
	Tables VIII and IX	Table X	Table XI			Table XIV	Fig. 5	Table XVI		
Conference Rooms and Executive Offices	55	5	0	60	54	5	10	30	45	-9
Secretarial, Drafting Offices	70	5	0	75	39	5	10	30	45	OK
Machine Shop, Shipping and Receiving Rooms	85	5	5	95	19	5	0	25	30	OK
	(a)	(b)	(c)	(d)*	(e)	(f)	(g)	(h)	(i)**	(j)***

* (d) = (a) + (b) + (c)

** (i) = (f) + (g) + (h)

*** (j) = (e) - (i) : When (j) $\geq$ 0, building noise reduction meets requirements;

When (j) < 0, additional building noise reduction is needed.

In Column (a) we list the continuous noise criteria; in Columns (b) and (c) the aircraft noise adjustment factors. The sum of the values in these columns is given in Column (d), giving us the aircraft noise criteria for the different work spaces. The needed noise reduction for each space, listed in Column (e), is the difference between the outside CNR of 114 and the noise criteria values of Column (d).

Because the building is located well to one side of the runway, with aircraft on Runway 8 flying past at a low vertical angle, there is a 5 dB ground-to-ground air attenuation correction entered in Column (f); comparison of the proposed factory layout with Fig. 5 (and considering the fact that there will be no windows in the east and west walls of the office space) indicate that a shielding correction of 10 dB can be assumed for the south wall. The estimated noise reduction values for the building construction, obtained from Table XV, are entered in Column (h). The sum of the contributions to total noise reduction (entered in Columns (f), (g) and (h) are listed in Column (i). These sums are compared with the needed noise reduction (Column (e)) to determine whether or not the building noise requirements are met.

The table shows the initial design to be satisfactory for the shop, the secretarial and drafting spaces, but not for the executive offices and conference rooms where a 9 PNdB deficiency exists. A glance at Table XV indicates that to increase the noise reduction by "beefing up" building and wall construction would require elimination of windows and use of walls and roof weighing approximately 40 to 80 lbs per sq ft. This is equivalent to four inches or more of dense concrete. As another approach, the side wall requirements could be achieved by substituting dense hollow concrete block of 8 inch thickness for the lightweight block initially planned.

Other approaches might be explored. The offices and conference rooms, for example, could be located along an inside wall; thus only the ceiling of these rooms would be exposed to the aircraft noise. With installation of a suspended ceiling over the rooms, relatively high values of noise reduction might be attained at moderate costs.

If, however, it was considered desirable to keep the executive offices and conference rooms along the outer walls and to provide windows for these rooms, one would have to consider installation of thick single glazing or, perhaps, double glazing, in order to limit the noise transmission through windows. For example, from Table XVI and Fig. 6, we learn that if the outer walls have 10% window area, with 1/4 inch glass windows sealed in place, the effective noise reduction of walls having 40 PNdB noise reduction without windows would be reduced to approximately 33 PNdB. This value of noise reduction for the composite wall structure is only 3 dB better than the initial design, and is 6 dB short of that needed to meet the room requirements.

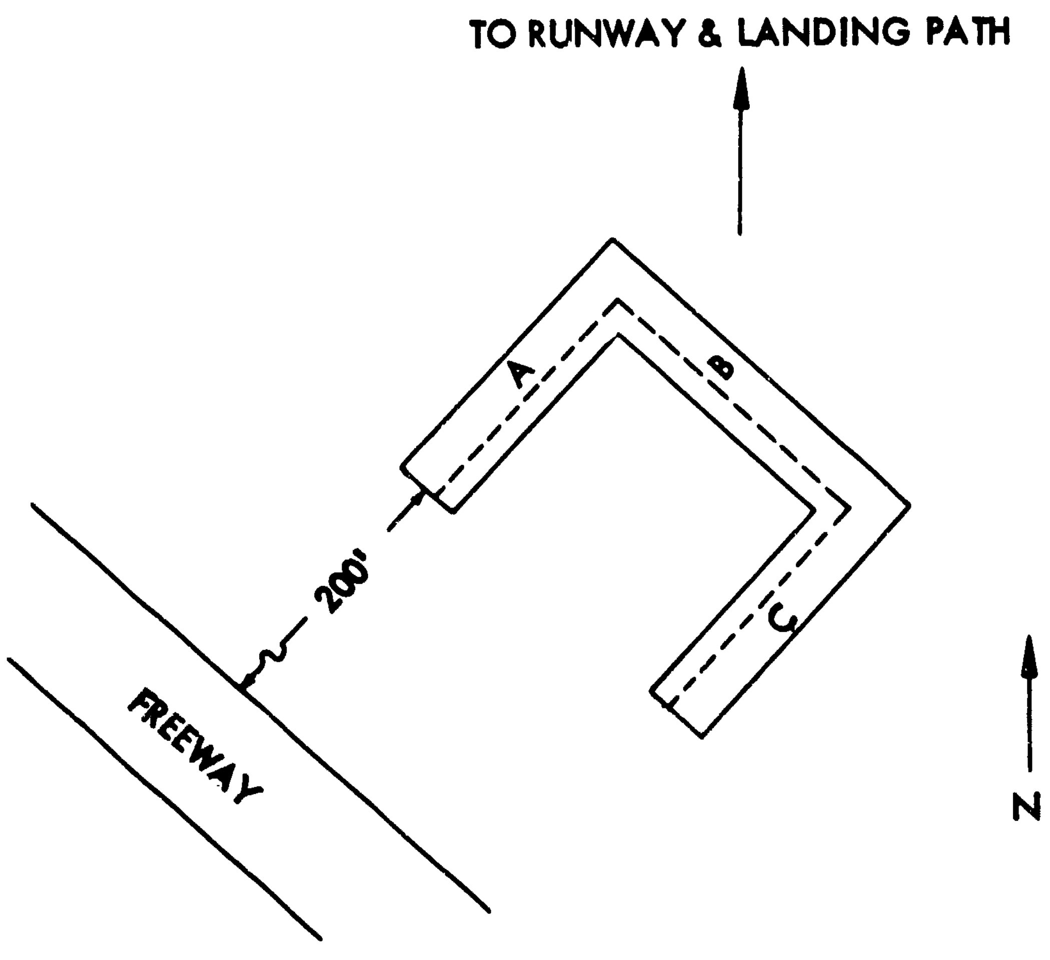
EXAMPLE 2 - Building Noise Reduction Requirements for a Proposed Motel Exposed to Aircraft Noise During Approach

For the same airport as in the previous example, consider the noise exposure for a proposed motel located at Position B in Fig. 8 (approximately 9000 ft from the beginning of Runway 8 and 1300 ft south of the flight path centerline). Based upon the flight operation information of Table XVI, we again estimate the perceived noise levels using Appendix A (or Reference 1). The resultant noise level information is shown in the following table:

Aircraft Type	Flight Oper.	R/W	Perceived Noise Level, PNdB	Activity Cor.	R/W Util Cor.	CNR
Turbojet and Turbofan	Landing	8	96	+5	0	101
Turbojet-Trip Under 2000 mi	Takeoff	26	107	-5	-15	87
Turbojet-Trip Over 2000 mi	Takeoff	26	113	-5	-15	83
Turbofan-Trip Under 2000 mi	Takeoff	26	102	0	-15	87
Turbofan-Trip Over 2000 mi	Takeoff	26	108	-5	-15	88

We consider here only the noise of landing operations on Runway 8 and takeoffs from Runway 26. The CNR values in this case are based upon nighttime activity; the corresponding activity and runway utilization corrections are given in the table, with the last column in the table listing the resulting CNR values. The maximum CNR value of 101 results from noise from landing operations; note that the actual noise levels during takeoff are considerably higher than those occurring during landings, but since takeoffs occur infrequently on Runway 26, the maximum CNR rating is governed by the frequent landing operations on Runway 8.

The arrangement of the motel is shown in more detail in the sketch below.



The motel faces an access road running parallel to a busy six-lane freeway with the nearest part of the motel about 200 ft from the edge of the freeway. The motel is to be a two story building of concrete block construction. Air conditioning is being considered. The roof will overhang the inner court walls to provide weather protection for the open stairs and walkways which provide access to the rooms.

From Fig. 2 we estimate the daytime freeway noise levels to be 84 PNdB. Conservatively, lacking actual measurement data, we might estimate that evening noise levels to be at least 5 PNdB less, or 70 PNdB. This level is much below the CNR value of 101 for aircraft noise, so aircraft noise is the major noise source to consider in design. However, we will want to check later to see that the building noise reduction will reduce freeway traffic noise sufficiently to meet the steady-state noise level design criteria.

Following Steps 6 through 10 of the procedure as we did in the previous example, we select a steady-state noise criterion for the motel rooms of 55 PNdB from Table VIII. Selecting a correction factor of +5 PNdB each from Tables XI and XII, we arrive at an aircraft noise criterion value of 55 + 5 + 5 = 65 PNdB. Subtraction of this value from the CNR of 101 yields a needed building noise reduction of 36 PNdB. For comparison, we note that the steady-state noise reduction requirement, based upon nighttime freeway traffic noise, is 79 minus 55 or 24 PNdB, a value significantly less than the noise reduction required for aircraft noise.

A study of Table XVI shows that with conventional construction and closed windows, we can expect 30 PNdB noise reduction for jet approach noise, 6 dB less than required to meet our design criterion. This 30 PNdB reduction can only be achieved with windows closed, which for summer occupancy of the rooms implies air conditioning. Now, if individual room air conditioners mounted in walls are used, a 30 PNdB noise reduction would probably not be achieved in practice even with windows closed, because of the sound transmission leak through the air conditioners. (We probably should not expect more than about 25 PNdB with this method of air conditioning.) With a central air conditioning system, and with reasonable noise control steps undertaken in the installation of the equipment ducting and ventilation openings, 30 PNdB could be realized with room windows closed. With windows sealed in place a maximum noise reduction of 35 PNdB should be attained.

At this point we can review the individual room situation more closely in order to get a more detailed picture of noise reduction requirements. From study of Fig. 5 we estimate that the wide overhang along the inner court walls will provide some shielding for the inner walls along building wings A and B. With a 10 dB benefit due to shielding, the noise reduction requirements for these walls in wings A and B are reduced to 26 dB, which can be achieved with either central or individual room air conditioning (with windows closed).

If we look at a typical room arrangement, (not shown) we notice that the windows in the rear wall open into the lavoratory, rather than directly into the motel room. If windows are closed, the lavoratory with door partially closed will effectively increase the wall noise reduction by approximately 5 PNdB. Thus, the back wall would yield in practice about 35 PNdB noise reduction which, for all practical purposes, satisfies the wall reduction requirements of 36 PNdB.

A feature not to be overlooked is roof construction which is critical with respect to attaining the required noise reduction for motel rooms on the second floor. By extrapolation from the values given in Table XVI, we estimate that the roof should weigh at least 10 lbs per sq ft to achieve the needed 36 PNdB noise reduction.

To review the design, the rear concrete block walls for the rooms appear adequate, provided no windows open directly into the motel rooms. With air conditioning provided (allowing windows to be closed) the front walls in wings A and B appear adequate with either individual or central air conditioning. However, because of the lack of shielding the front walls of rooms in wing C will not meet requirements unless windows are sealed in place and openings for air conditioners are eliminated. This requirement indicates the need for a central air conditioning system to serve at least this wing of the motel. Lastly, the roof should weigh at least 10 lbs per sq ft.

The above discussion, of course, does not exhaust design possibilities or alternatives. One might at this time wish to review the basic building arrangement and consider modification of the original "U" layout. Other room arrangements and choices of wall construction might also be considered.

EXAMPLE 3 - Development of Land Sensitivity Zones

We will now illustrate application of the procedures in defining Noise Sensitivity Zones useful in land planning and land zoning. We will consider the same airport situation considered in the first two examples, and will take into account noise from both flight operations and ground runups.

The boundaries for the Noise Sensitivity Zones are defined in terms of CNR values of 90, 100, and 115 (as listed in Table VII on page 29). Thus, our task is to construct contours for these three CNR values. In reverse to the procedures employed in the previous examples, we now must determine the PNdB levels corresponding to the three CNR values in order to select the proper perceived noise level contours.

Determination of the proper perceived noise level values for the CNR 115 boundary between Noise Sensitivity Zones III and IV will allow us to easily select the appropriate perceived noise levels for the remaining Noise Sensitivity Zone boundaries.

Information needed to select the proper perceived noise level contours for the CNR 115 contour is tabulated in Table XIX. (This information is based upon the operational data presented earlier in Table XVII.)

Table XIX shows the various steps in selection of the proper noise contours for takeoff and landing operations for Runways 8 and 26, takeoff roll contours for Runway 8 and 26, and ground runups. Note that since we begin with CNR values, we must subtract (rather than add) the pertinent corrections, i.e., PNdB = CNR - (corrections).

Thus, in selecting the appropriate perceived noise level corresponding to CNR 115 for takeoffs on Runway 26 of turbofan transports departing for trips under 2000 miles, we start with the CNR value of 115. To this value we subtract an activity correction of 0, a runway utilization correction of -15 and a contour set correction of -5 to yield a perceived noise level value of 115 - (0) - (-15) - (-5), or 135 PNdB.

The next step in the development of the CNR contours would be to transfer the contours to an overlay (tracing) for comparison. The contour that includes the others is the one that

TABLE XIX

SELECTION OF PERCEIVED NOISE LEVEL CONTOURS
FOR EXAMPLE 3

Aircraft Type	Oper.	R/W	CMR	Activity Correc.[1]	R/W Util Cor.[2]	Contour Set[3]	Contour Set Cor.[3]	Noise Contour
Turbojet-Trips under 2000 mi	Takeoff	8	115	0	0	1A	0	115
Turbojet-Trips over 2000 mi	Takeoff	8	115	-5	0	1B	0	120
Turbofan-Trips under 2000 mi	Takeoff	8	115	0	0	1A	-5	120
Turbofan-Trips over 2000 mi	Takeoff	8	115	-5	0	1B	-5	125
Turbojet-Trips under 2000 mi	Takeoff	26	115	0	-15	1A	0	130
Turbojet-Trips over 2000 mi	Takeoff	26	115	-5	-15	1B	0	135
Turbofan-Trips under 2000 mi	Takeoff	26	115	0	-15	1A	-5	135
Turbofan-Trips over 2000 mi	Takeoff	26	115	-5	-15	1B	-5	140
Turbojet and Turbofan	Landing	8	115	+5	0	3B	0	110
Turbojet	Takeoff	8	115	0	0	6	0	115
Turbofan	Roll	8	115	+5	0	7	0	110
Turbojet	Takeoff	26	115	0	-15	6	0	130
Turbofan	Roll	26	115	0	-15	7	0	125
Turbojet	Ground Runup	--	95	-5	-	6	0	100
Turbofan	Ground Runup	--	95	0	-	7	0	95

1 Table III for flight operations; Table IV for ground runups

2 Table III

3 Appendix A

should be selected to define operations on that runway. If contours should intersect one another, use the outer envelope of the contours.

Thus, we find after comparing contours on a transparent overlay that for takeoffs from Runway 8, the CNR 115 contour should be based upon a combination of the 115 PNdB contour for turbojet aircraft (trips under 2000 miles) and the 120 PNdB contour for turbojet aircraft (trips over 2000 miles). For Runway 26 the CNR 115 contour will be based upon the 110 PNdB contours for landing of turbojet and turbofan aircraft.*

Figure 9 shows the results of following the above procedure. You will note that the boundary between Noise Sensitivity Zones III and IV is shown as a broken line at distances of more than about 5 miles from the airport. The broken line stresses the approximate nature of the Noise Sensitivity Zone boundaries at large distances from the airport. As distances from airport runways increase, aircraft flight paths usually become increasingly divergent, thus reducing the accuracy of the noise contour representation. Field observation is extremely helpful in establishing the accuracy and reasonableness of the flight paths and noise contours at large distances from the airport.

We should mention again that the contours defining Noise Sensitivity Zones should be regarded as guides in estimating noise exposure and land use compatibility, not as absolute geographic boundaries. For example, the noise exposure on the ground may be modified in localized areas due to terrain features which are not taken into account in the construction of the generalized noise contours of Appendix A. After construction of the Noise Sensitivity Zone boundaries, field inspection and observation would be helpful in determining the applicability of the contours in areas where local topographic features might cause deviations in the predicted noise exposure.

---

* One problem that may arise in the development of the Noise Sensitivity Zone boundaries is that the contours of Appendix A (or Reference 1) will not necessarily cover the needed range of perceived noise level values. Information needed to construct additional perceived noise level contours is given in Appendix B of Reference 1.

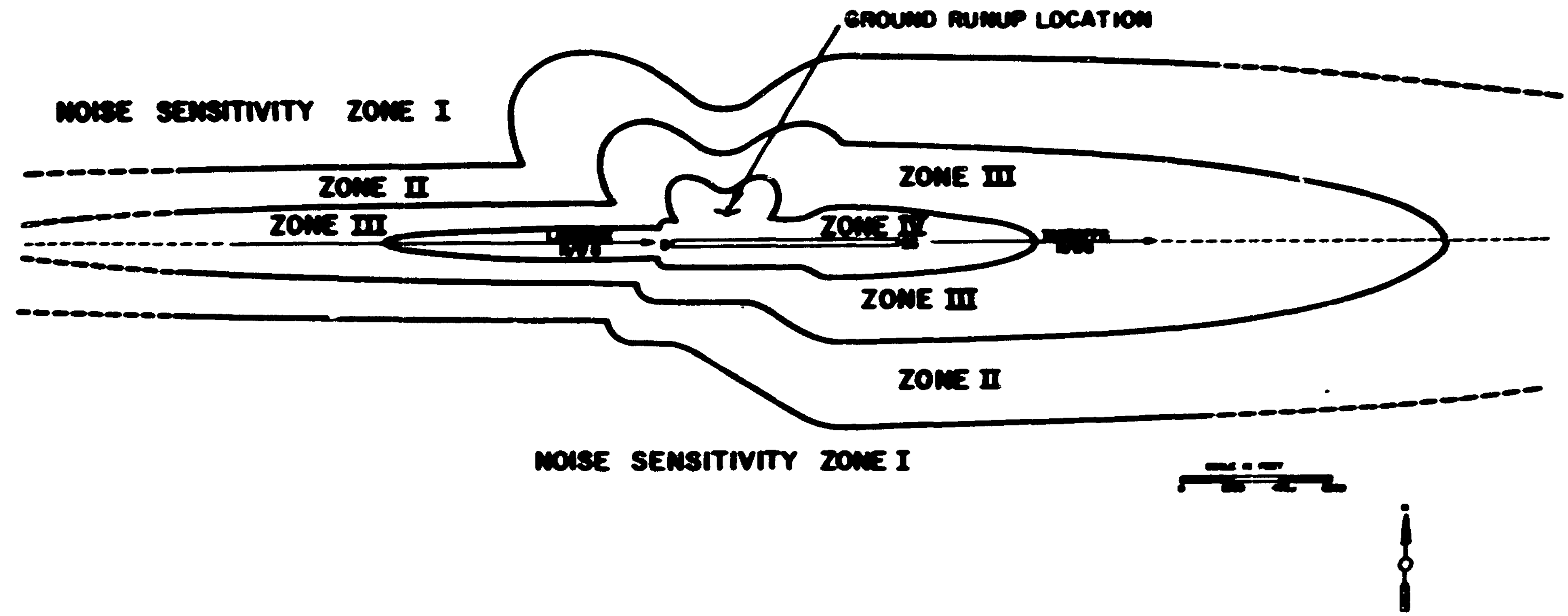


FIGURE 9. LAND USE NOISE SENSITIVITY ZONES FOR HYPOTHETICAL AIRPORT OF FIGURE 8

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APPENDIX A

PERCEIVED NOISE LEVEL CONTOURS AND TABLES FOR CALCULATING COMPOSITE NOISE RATING CONTOURS

This appendix contains a set of perceived noise level contours and tables useful in determining the perceived noise level contours for flight and ground runup operations. The information given in this appendix is extracted directly from Reference 1.

Contour Sets 1 through 5 present perceived noise level contours for typical takeoffs and landings by varied types of military turbojet aircraft, multi-engine turbofan, turbojet, turboprop and piston-powered transport aircraft, and selected helicopter aircraft. Contour Sets 6 through 8 present perceived noise level contours for ground runups of turbofan and turbojet engines.

Tables A-1 and A-2 present classifications of military aircraft in terms of noise produced during takeoff or runup operations. Table A-3 is a guide for selecting the proper noise contours according to the aircraft classification given by Tables A-1 and A-2.

TABLE A-1

CLASSIFICATION OF MILITARY AIRCRAFT FOR TAKEOFF OPERATIONS

Flight Group 1	
B58	Afterburner
Flight Group 2	
F100	Afterburner
F101	"
F102	"
F104	"
F105	"
F106	"
F11	"
F8	"
F4	"
A5	"
F6	"
B58	Military
Flight Group 3	
F104	Military
F106	"
F4	"
F4C	"
Flight Group 4	
F3	Afterburner
Flight Group 5	
F100	Military
F101	"
F102	"
F105	"
F11	"
A5	"
F6	"
F8	"
A3	"
F3	"
F86K	Afterburner
F86L	"
Flight Group 5 (cont'd)	
F89	Afterburner
F94C	"
T38	"
Flight Group 6	
F/RF 84F	Military
T33/F80	"
F86E	"
F86F	"
F86H	"
F89	"
F94C	"
F86K	"
F86L	"
B57	"
B66	"
A4	"
F9	"
F84	"
T38	"
T39	"
C140	"
T37	"
Flight Group 7	
B52F/G	Military
Flight Group 8	
KC-135A	Military
C135A	"
B52H	"
Flight Group 9	
C135B	Military
Flight Group 10	
B47	Military

TABLE A-2

CLASSIFICATION OF MILITARY AIRCRAFT
FOR RUNUP OPERATIONS

Runup Group 1	Runup Group 2	Runup Group 3
F100 Afterburner	F100 Military	F/RF 84F Military
F101 "	F101 "	T33/F80 "
F102 "	F102 "	F86E,F,H "
F104 "	F104 "	F89 "
F105 "	F105 "	F94C "
F106 "	F106 "	F86K,L "
F11 "	F11 "	B57 "
F8 "	F8 "	B66 "
F3H "	F3 "	A4 "
F43 "	F4C "	F9 "
A5 "	A5 "	F84 "
F6 "	F6 "	T37 "
B58 "	A3 "	T38 "
	B58 "	T39 "
	B52F/G "	C140 "
	KC135A "	B47 "
	F86K,L Afterburner	
	F89 "	
	F94C "	
	T38 "	

NOTE: "Military" in above listing includes runup operations from 90% rpm up through military power.

For multi-engine aircraft, runups are assumed to occur for one engine only.

TABLE A-3

CHART FOR SELECTION OF NOISE CONTOURS

AIRCRAFT CATEGORY	OPERATION	AIRCRAFT TYPE*	CONTOUR SET	CORRECTION TO CONTOUR PNdB
CIVIL	Takeoffs	Turbojets** Trips under 2,000 mi	1A	0
		Turbojets** Trips over 2,000 mi	1B	0
		Turbofans** Trips under 2,000 mi	1A	-5
		Turbofans** Trips over 2,000 mi	1B	-5
		Piston	4	0
		Turboprop	4	-5
		Helicopters (Sikorsky S-61 Vertol 107, and Vertol 44)	5A	0
	Landings	Turbojet**	3B	0
		Turbofan**	3B	0
		Piston	3A	0
		Turboprop	3A	0
		Helicopters-Vertol 44	5B	-10
		Helicopters-Vertol 107 Sikorsky S-61	5B	0
	Runups	Turbojet	6	0
		Turbofan	7	0
MILITARY	Takeoffs	Flight Group 1	2A	+5
		" " 2	2A	0
		" " 3	2A	-5
		" " 4	2B	+5
		" " 5	2B	0
		" " 6	2B	-5
		" " 7	2C	0
		" " 8	2C	-5
		" " 9	2C	-10
		" " 10	2D	0

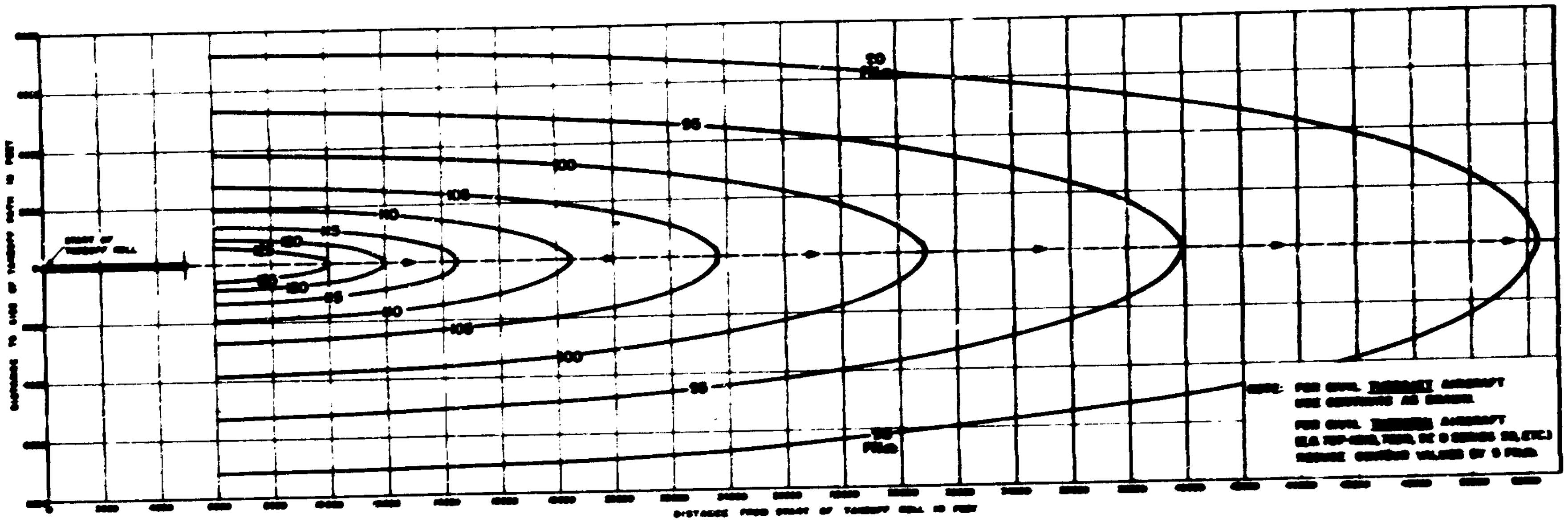
TABLE A-3 (cont'd)

AIRCRAFT CATEGORY	OPERATION	AIRCRAFT TYPE**	CONTOUR SET	CORRECTION TO CONTOUR PNdB
MILITARY		All jets	3B	0
	Landings	Turboprop	3A	0
		Piston	3A	0
		B52H-C135B	7	0
		Runup Group 1	8	+5
	Runups	" " 2	8	0
		" " 3	8	-5

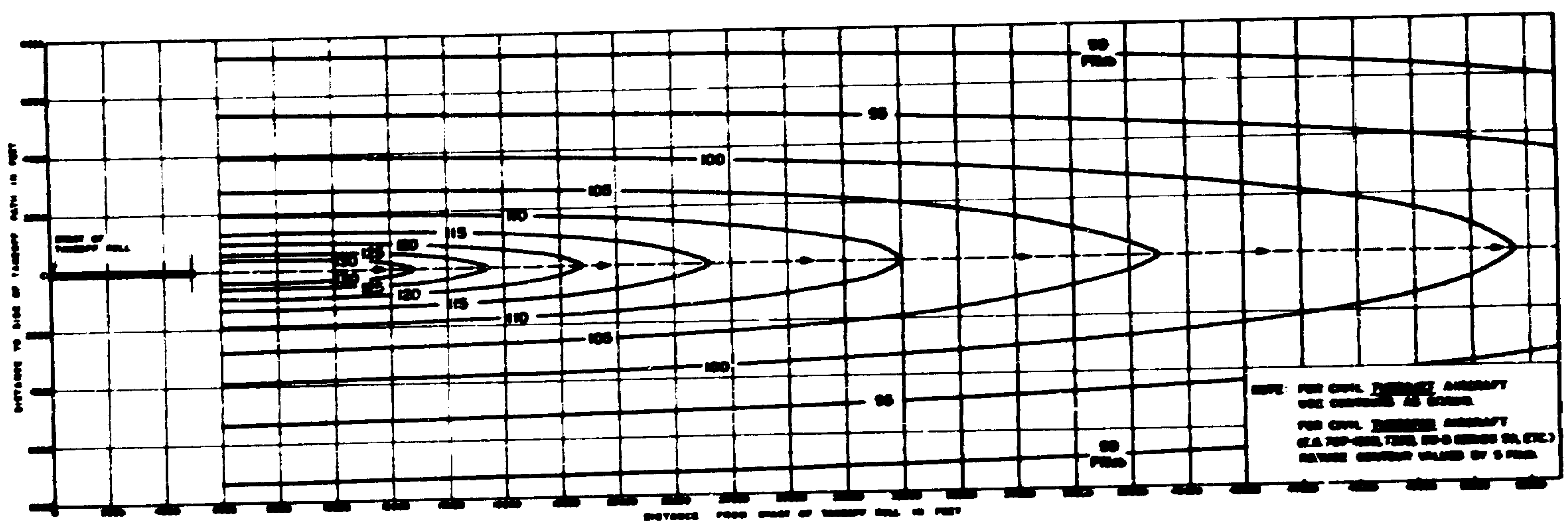
* Other designations for aircraft types are as follows: pure jet for turbojet; prop jet for turboprop; fan jet for turbofan; and conventional or propeller for piston engine.

** The noise contours apply to the larger four engine jet transport aircraft such as the Boeing 707 and 720, DeHavilland Comet, Convair 880 and 990, and Douglas DC-8.

NOTE: For turbojet aircraft takeoffs, the appropriate noise contours apply for water injection ("wet" takeoff) as well as "dry" takeoff conditions.



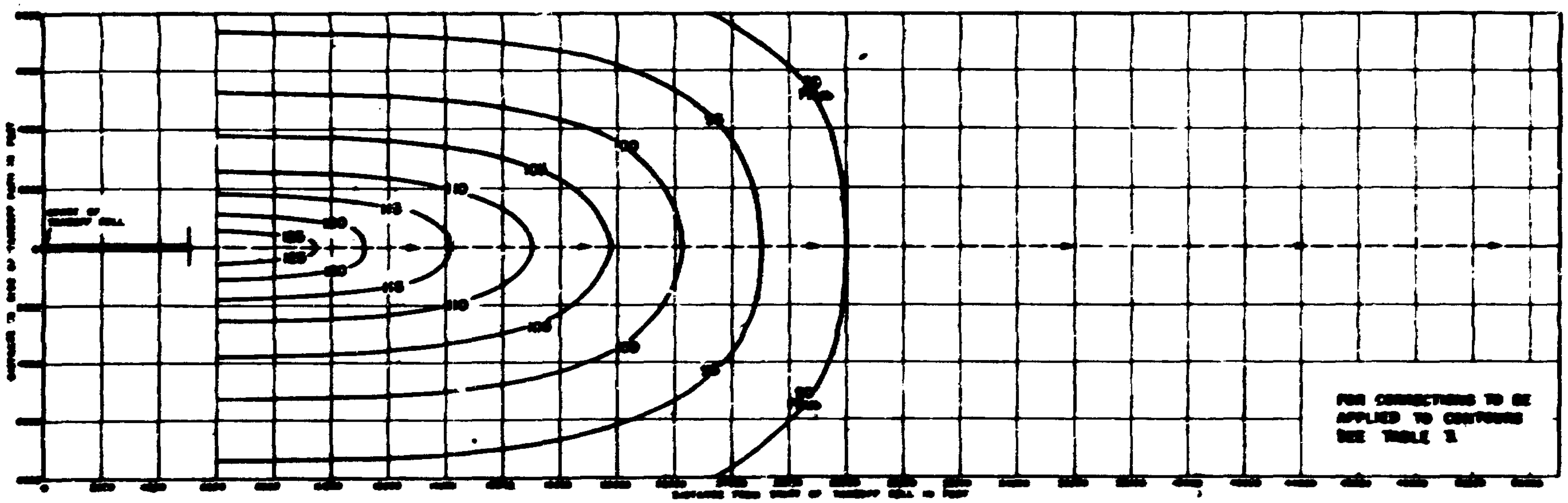
Ⓐ TRIP LENGTH LESS THAN 2000 MILES.



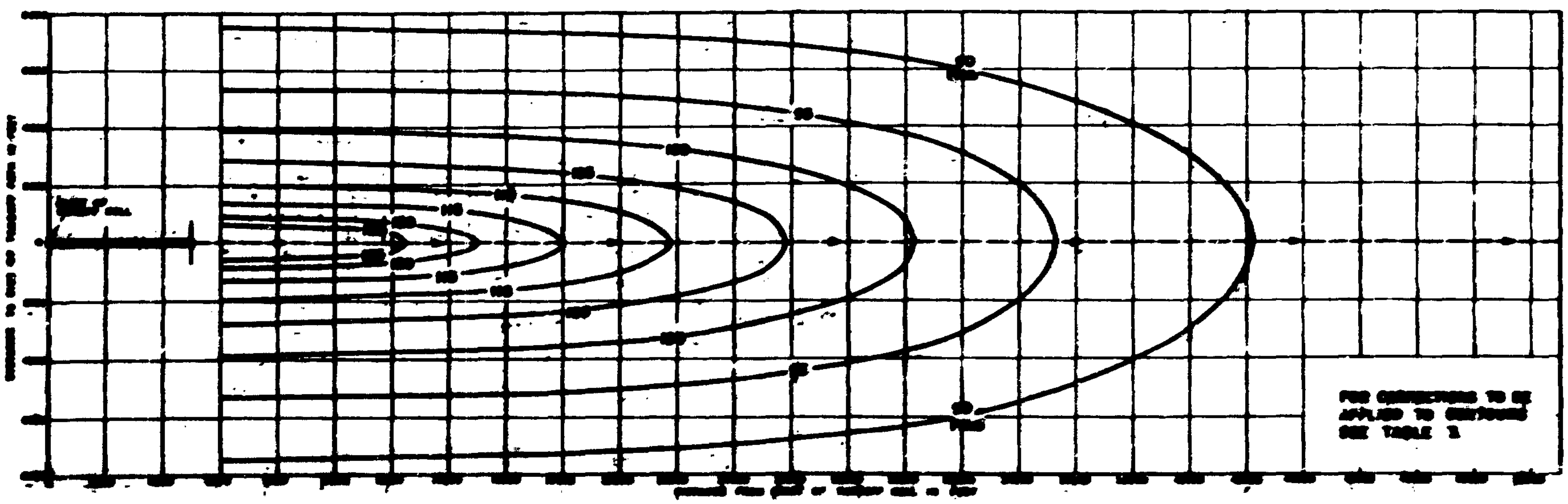
Ⓑ TRIP LENGTH MORE THAN 2000 MILES.

PERCEIVED NOISE LEVEL CONTOURS FOR TAKEOFFS OF CIVIL JET TRANSPORTS.

CONTOUR SET I



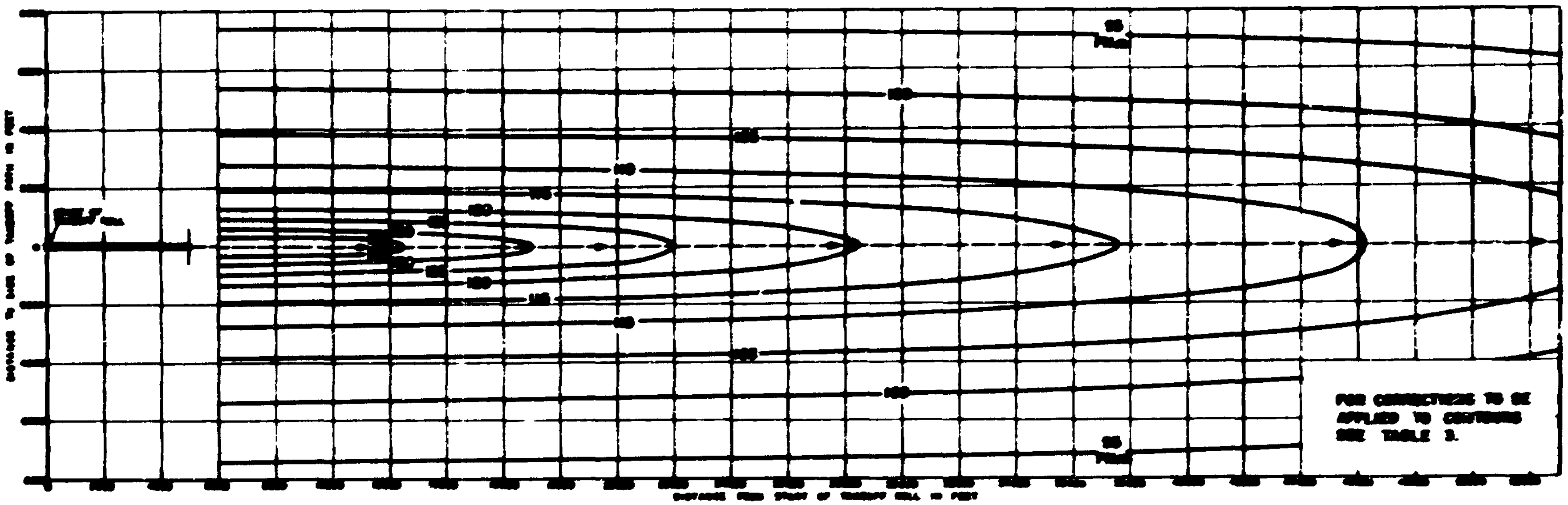
Ⓐ FLIGHT PROFILE A.



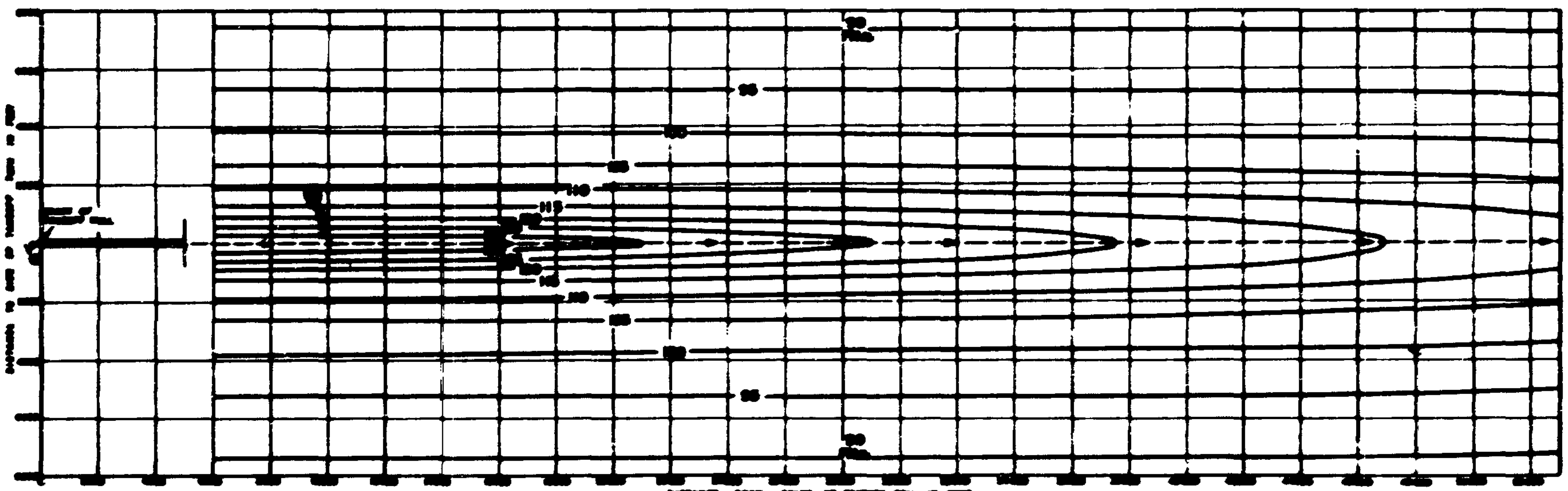
Ⓑ FLIGHT PROFILE B.

PERCEIVED NOISE LEVEL CONTOURS FOR TAKEOFFS OF MILITARY JET AIRCRAFT.

CONTOUR SET 2



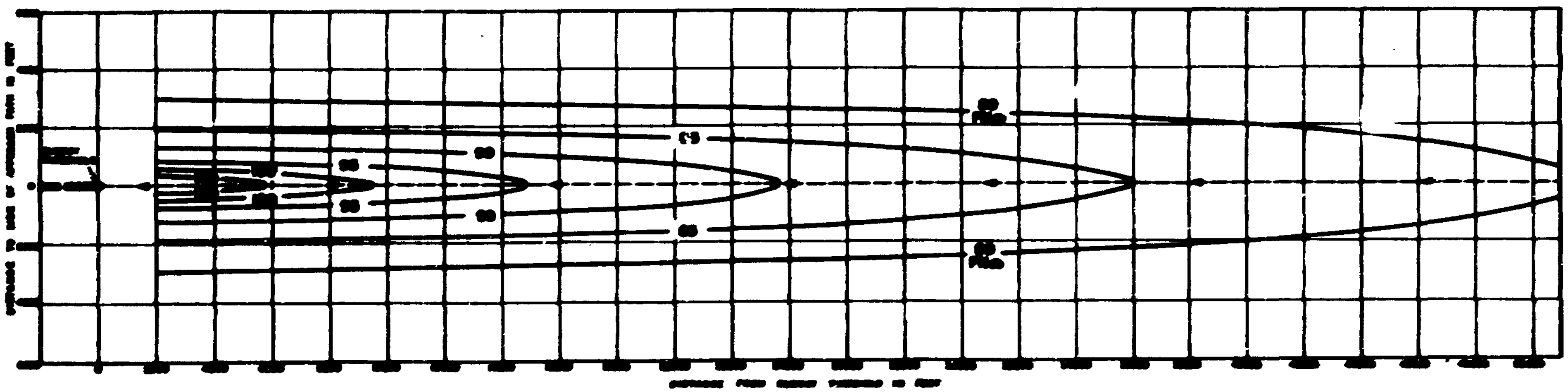
Ⓒ FLIGHT PROFILE C.



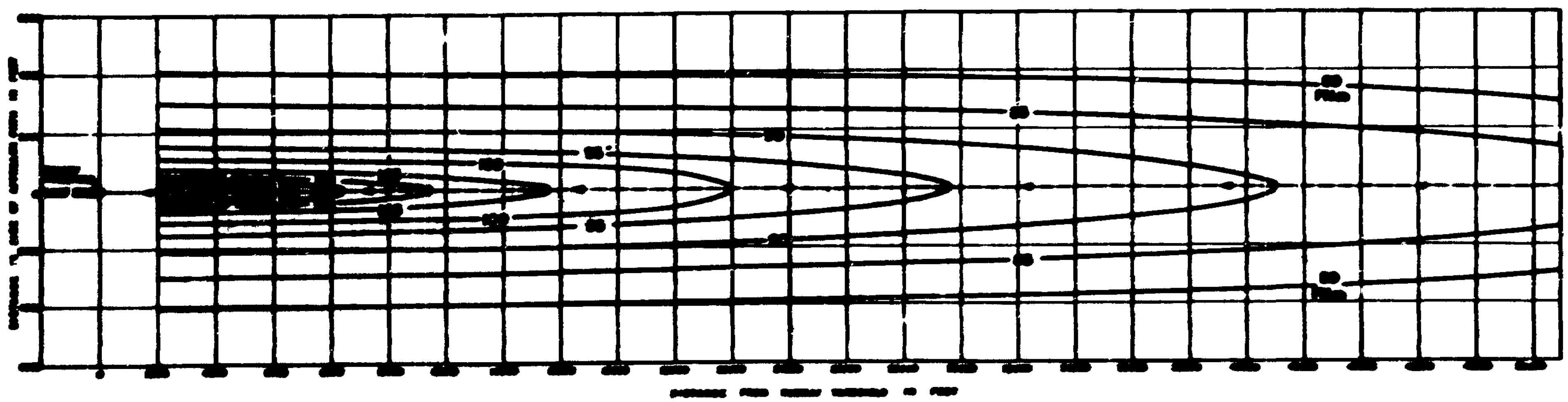
Ⓓ FLIGHT PROFILE D.

PERCEIVED NOISE LEVEL CONTOURS FOR TAKEOFFS OF MILITARY JET AIRCRAFT.

CONTOUR SET 2 (CONT.)



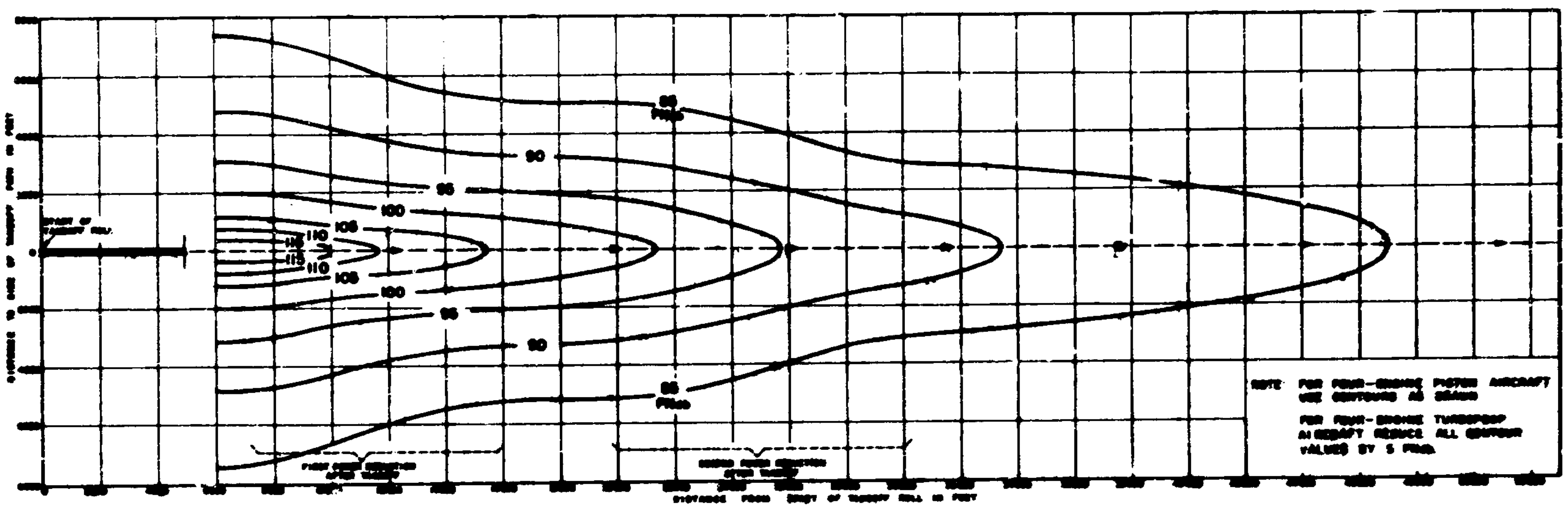
Ⓐ FOUR-ENGINE PISTON AND TURBOPROP AIRCRAFT.



Ⓑ TURBOJET AND TURBOFAN AIRCRAFT.

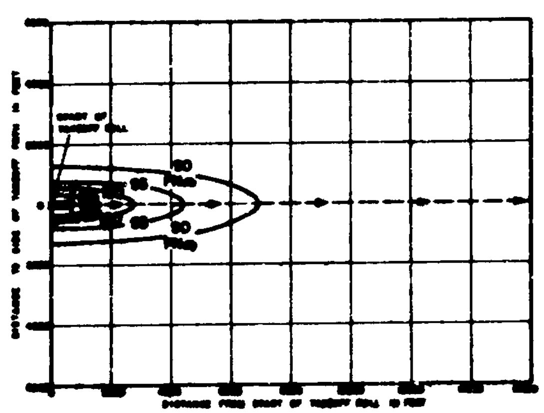
PERCEIVED NOISE LEVEL CONTOURS FOR CIVIL AND MILITARY LANDINGS

CONTOUR SET 3

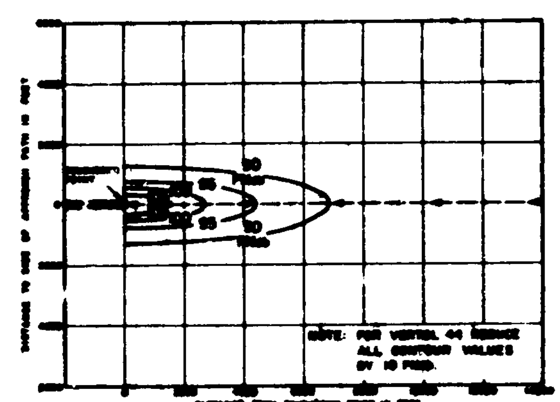


PERCEIVED NOISE LEVEL CONTOURS FOR TAKEOFFS OF FOUR-ENGINE PISTON AND TURBOPROP AIRCRAFT.

CONTOUR SET 4



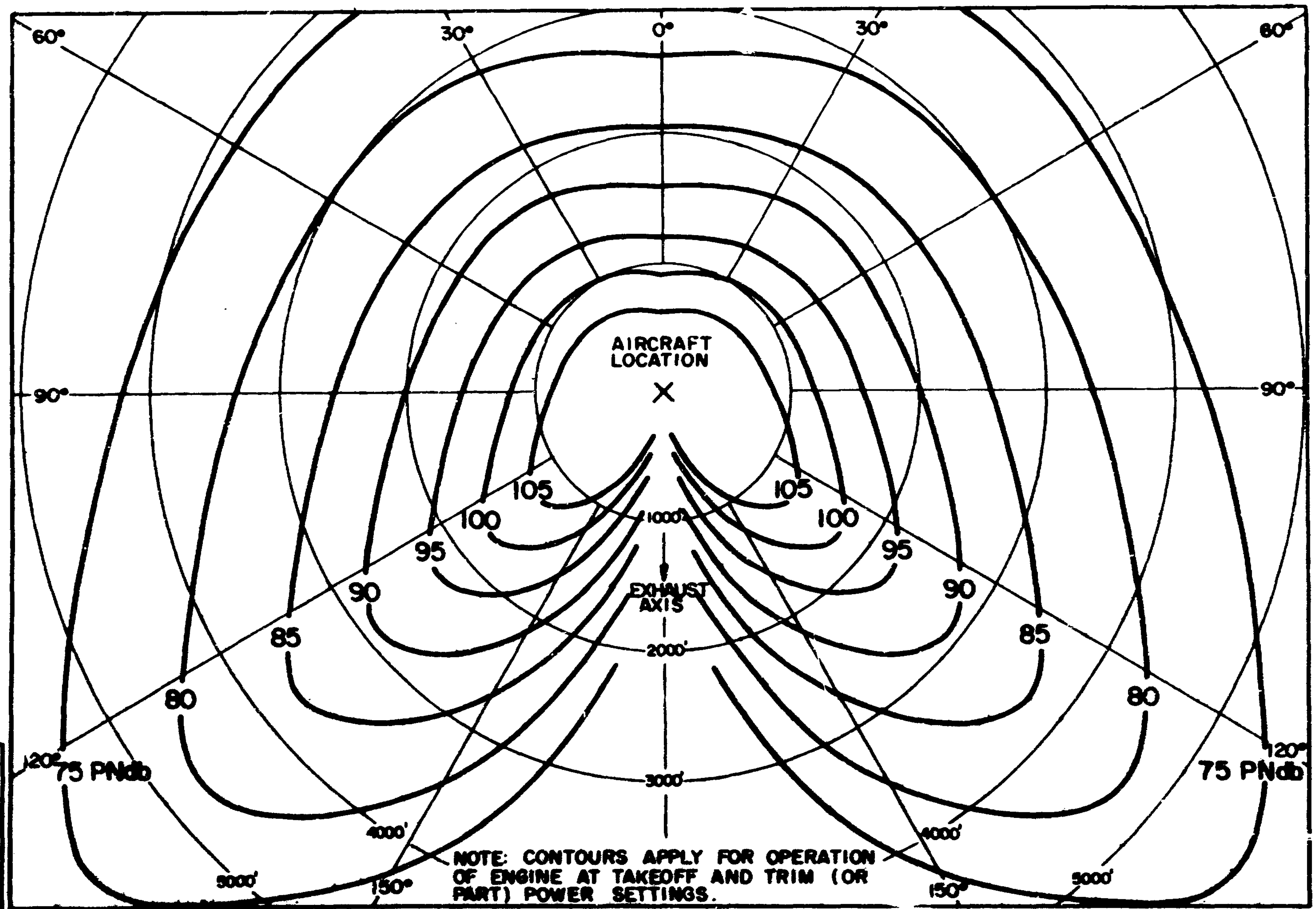
Ⓐ TAKEOFFS



Ⓑ LANDINGS

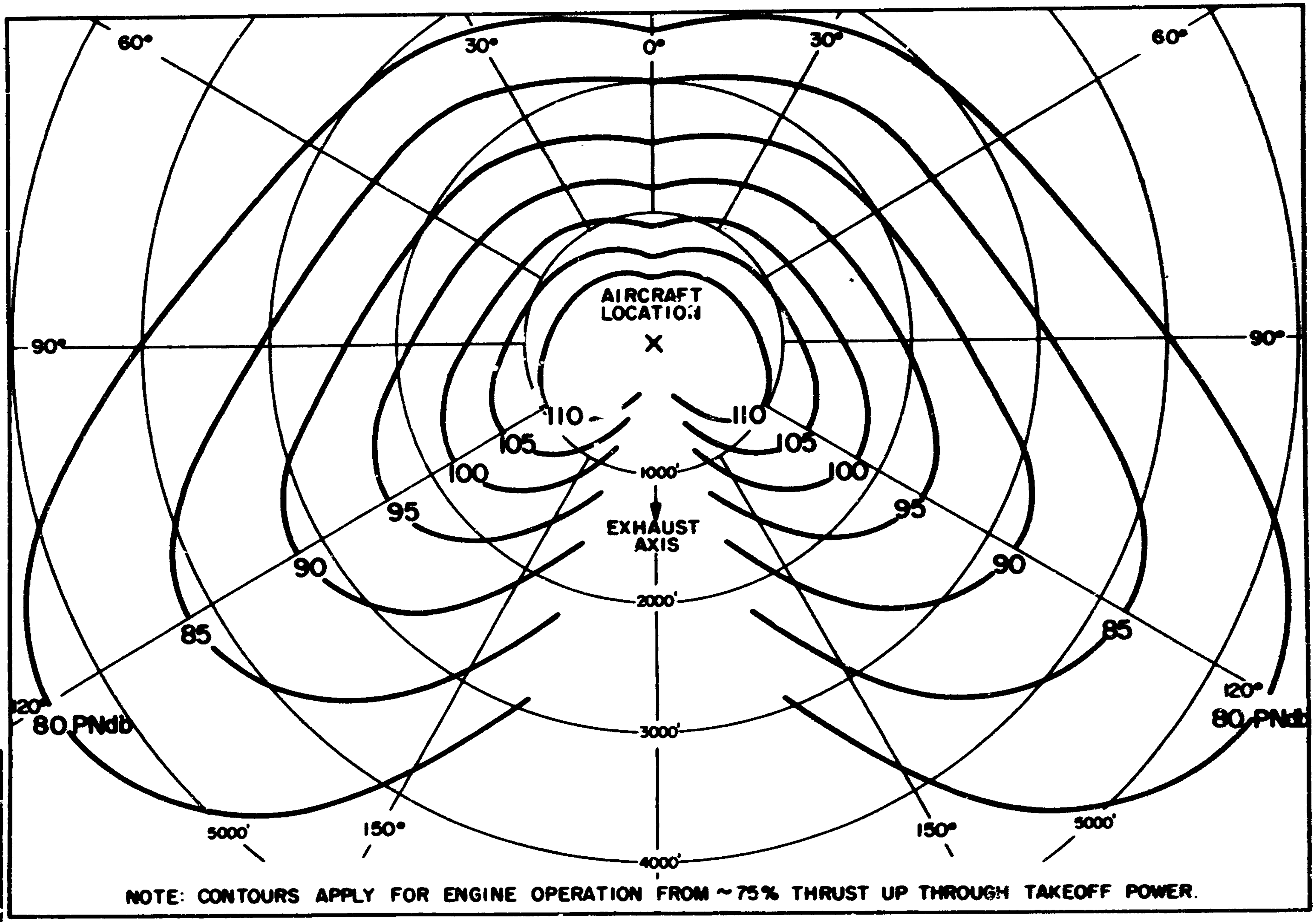
PERCEIVED NOISE LEVEL CONTOURS FOR TAKEOFFS AND LANDINGS OF SIKORSKY S-61, VERTOL 44, AND VERTOL 107 HELICOPTER OPERATIONS AT AIRPORTS.

CONTOUR SET 5



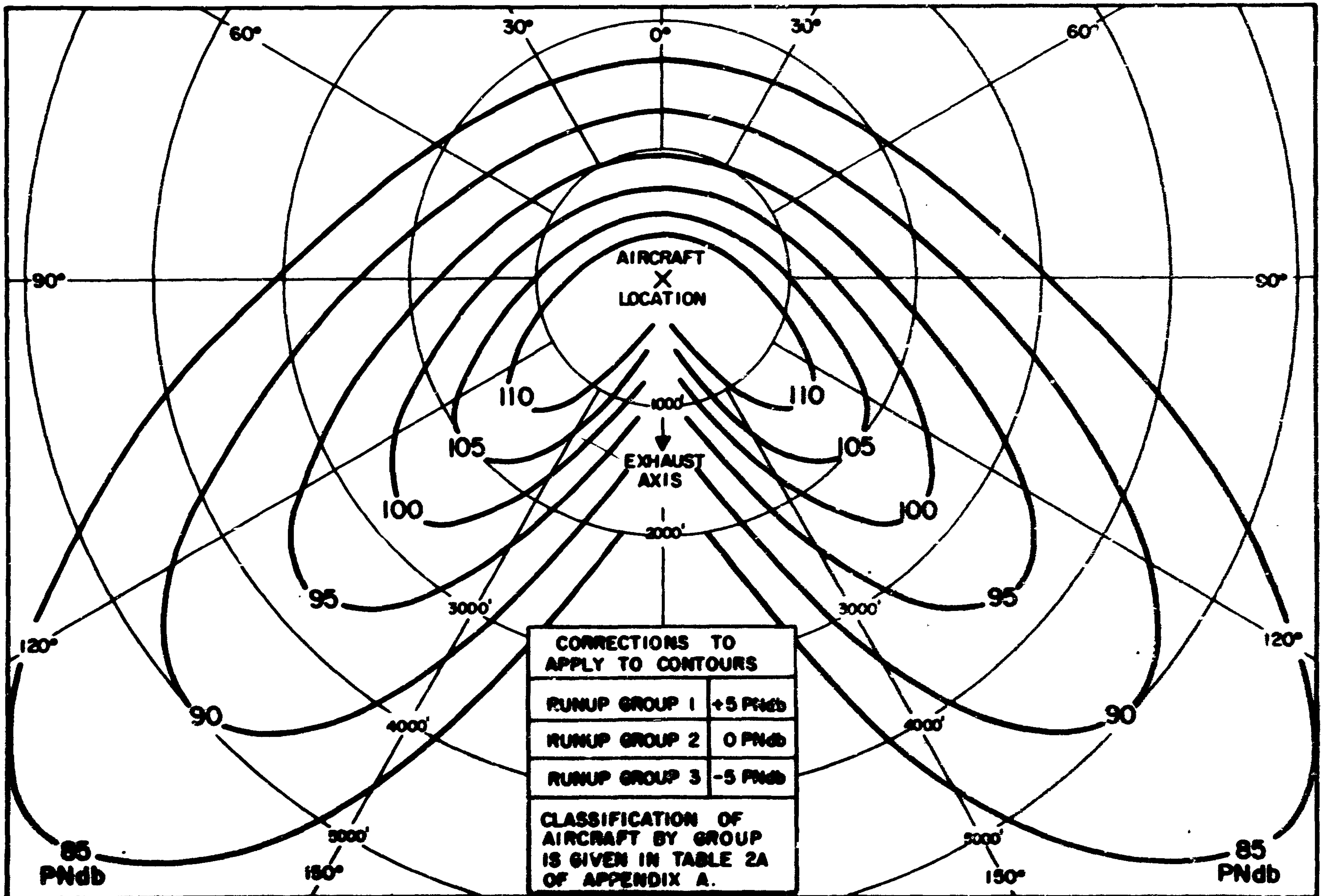
PERCEIVED NOISE LEVEL CONTOURS—ONE ENGINE RUNUPS.
CIVIL JET AIRCRAFT—NON-TURBOFAN ENGINES.

CONTOUR SET 6



PERCEIVED NOISE LEVEL CONTOURS—ONE ENGINE RUNUPS.
CIVIL AND MILITARY JET AIRCRAFT WITH TURBOFAN ENGINES.

CONTOUR SET 7



CORRECTIONS TO APPLY TO CONTOURS	
RUNUP GROUP 1	+5 PNdb
RUNUP GROUP 2	0 PNdb
RUNUP GROUP 3	-5 PNdb

CLASSIFICATION OF AIRCRAFT BY GROUP IS GIVEN IN TABLE 2A OF APPENDIX A.

PERCEIVED NOISE LEVEL CONTOURS—ONE ENGINE RUNUPS.
MILITARY JET AIRCRAFT.

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APPENDIX B

APPROXIMATIONS INVOLVED IN DESCRIBING BUILDING NOISE REDUCTION IN TERMS OF A DIFFERENCE IN PERCEIVED NOISE LEVELS

The term "noise reduction" (as employed throughout this report) indicates the difference in noise levels (generated by a source located outside a building) measured outside and inside the building. The noise reduction is a frequency dependent quantity, most often described by means of a curve plotted as a function of frequency.[21,24] Simplification in description of the noise reduction in terms of a single number inevitably produces some error.* This appendix summarizes the analysis undertaken to determine whether or not the building noise reduction might be expressed in terms of a single number, a difference in perceived noise levels which can be used in the procedure for estimating land use compatibility.

In reviewing the concepts underlying the perceived noise level and the methods used to calculate the perceived noise level, one would expect that the difference in perceived noise levels would vary with the type of noise since the spacing and shape of the family of curves relating the sound pressure level in frequency bands (octave, third-octave, etc.) and noisiness are not uniform (see Fig. 6 of Reference 2). Thus, changes in perceived noise level afforded by a particular building construction will vary with the amplitude and relative frequency content of the impinging noise field.

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* There is already considerable simplification introduced in the very concept of expressing the building noise reduction as a curve (or a set of values) which can be uniquely assigned to a particular type of building construction. Many other physical factors (room size and shape, amount of sound absorption in the room, measurement location inside or outside the room, and direction of the impinging sound waves), influence the noise reduction values measured in the field in a particular building or room. Fortunately, for most common types of structures the variations in building noise reduction resulting from variations in such physical factors is reasonably small.[25]

To investigate this problem we considered the following:

(a) The "outside" noise spectra of concern are those produced by propeller and jet aircraft during takeoff and approach at distances of 500 ft to 3000 ft from the aircraft.

(b) The resulting noise levels inside buildings will not usually be low enough to be near the threshold of hearing where the response curves (noisiness vs sound pressure levels) have considerable curvature.

(c) Some err. .s, on the order of $\pm$ 3 dB, may be tolerated as a reasonable price to pay for convenience of speed and calculation; this order of approximation is consistent with other approximations in the calculation procedures.

As an initial step in a..lysis, nine basic octave band noise spectra were sel...ed ..m available aircraft noise data; five spectra were of aircraft approach flyovers and four were of aircraft takeoff flyovers. Noise spectra produced by propeller transport aircraft, military turbojets, commercial turbojet and turbof . transport aircraft were selected.* The nine spectra, representative of noise levels at a distance of 1000 ft, are tabulated in Table B-1.

From each of the basic spectra of Table B-1, we then generated additional noise spectra for distances of 250, 500, 2000, and 3000 ft. Nine sets of spectra were based upon air-to-ground sound attenuation curves. Two additional sets of spectra were generated using typical air-to-ground attenuation curves.

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* All of the spectra except No. 2A represent composite spectra produced by averaging the noise spectra produced by more than one type of the aircraft (based upon noise data found in our files). Spectrum No. 2A is based upon the particular noise levels produced by Navy F-4B aircraft on approach. This octave-band spectrum, non-typical of most military jet aircraft approach noise, was introduced in the calculations as an example of the extreme limits in the range of noise spectra encountered in aircraft flyovers.

Next, eight sets of building noise reduction values were selected. Four sets were those of noise reduction values for conventional lightweight structures (with and without windows open);21/ the remaining four sets were derived from the definition of the sound transmission class (STC) curves given in ASTM E90-61T.* These sets of noise reduction values are tabulated in Table B-2.

The sets of building noise reduction values were then subtracted from the sets of noise spectra to yield corresponding sets of "inside" noise spectra. The perceived noise levels of "outside" and "inside" noise spectra were calculated. The differences between the outside and the inside perceived noise levels for each of the noise reduction cases were then tabulated and analyzed.

The analysis showed that:

(a) The variation in perceived noise level differences with distance for the same kind of aircraft noise was small, generally not exceeding 1 to 2 PNdB over a distance range from 500 to 3000 ft.

(b) The variation in perceived noise level differences with type of noise spectra was considerably larger, ranging from 4 to 13.5 PNdB. The variation increased with the magnitude of the wall noise reduction, with 4 PNdB being observed for the lighter walls and 13.5 PNdB observed for the heaviest wall. (This might be anticipated from study of Fig. 6 of Reference 2 since as wall noise reduction is increased, the "inside" noise levels decrease with greater liklihood that the perceived noise level will be calculated in ranges where there is considerable curvature in the curves relating noisiness and the sound pressure levels in a given frequency.)

Table B-3 illustrates the variation with type of spectra by showing the average difference in perceived noise levels calculated at 1000 and 2000 ft distances for each of the nine excitation spectra and each of the eight building noise

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* See Footnote on page 46.

reducti.. curves. The last column of Table B-3 shows the total range in noise reduction differences observed for each of the eight building reduction values. Table B-3 shows that for the same type of aircraft noise reduction values during approach are consistently somewhat higher than those calculated for takeoff. Further, the highest values of noise reduction are calculated for the approach spectra of civil jet or fan aircraft.

Study of the variations listed in Table B-3 showed that the approximations introduced in describing building noise reduction as a difference in perceived noise level could be reduced to acceptable limits by assigning two values of the perceived noise level differences for each noise reduction curve. One value applies for takeoffs of all aircraft and for landings of propeller or military jet aircraft; the other value (obtained by adding 5 PNdB to the takeoff noise reduction value) applies when calculating the building noise reduction for approach noise from either commercial turbojet or turbofan aircraft.

TABLE B-1

REPRESENTATIVE OUTSIDE AIRCRAFT FLYOVER NOISE LEVELS
ASSUMED IN NOISE REDUCTION CALCULATIONS
(1000 ft Distance From Aircraft)

	Spectrum Number	Aircraft Type	Sound Pressure Level in dB re 0.0002 Microbar -- Octave Frequency Band - cps							
			20-75	75-150	150-300	300-600	600-1200	1200-2400	2400-4800	4800-10,000
APPROACH	1	Propeller (Piston) Transport	80	80	78	74	70	65	61	53
	2	Military Turbojet Fighter	81	80	84	84	81	76	67	54
	2A	Navy F-4B Aircraft	89	90	93	96	103	94	84	65
	3	Civil-Turbojet Transport	77	78	82	84	84	83	79	70
	4	Civil-Turbofan Transport	77	78	79	78	77	85	85	75
TAKEOFF	5	Propeller (Piston) Transport	90	96	95	87	81	73	68	58
	6	Military-Turbojet Fighter	97	100	104	105	101	93	86	75
	7	Civil-Turbojet Transport	99	104	107	105	103	101	95	87
	8	Civil-Turbofan Transport	98	102	102	100	96	93	97	86

TABLE B-2

BUILDING CONSTRUCTION NOISE REDUCTION VALUES
ASSUMED IN NOISE REDUCTION CALCULATIONS

Noise Reduction Curve	Noise Reduction in dB Octave Frequency Band - cps							
	20-75	75-150	150-300	300-600	600-1200	1200-2400	2400-4800	4800-10,000
A - Wood Frame-Residential, Windows Closed	18	18	21	24	27	30	30	30
B - Wood Frame-Residential, Windows Open	12	12	14	16	18	20	20	20
C - Wood Frame Air Base Bldg. Windows Closed	15	19	25	28	33	37	40	46
D - Wood Frame Air Base Bldg. 0.1% open area	15	19	24	25	28	29	29	30
STC - 20	0	0	7	15	18	20	20	20
30	0	8	17	25	28	30	30	30
40	9	18	27	35	38	40	40	40
60	29	38	47	55	58	60	60	60

TABLE B-3

NOISE REDUCTION EXPRESSED AS DIFFERENCES
IN PERCEIVED NOISE LEVELS*

Noise Reduction Curves (See Table B-2)	Aircraft Noise Spectra (See Table B-1)									Range
	Approach					Takeoff				
	1	2	2A	3	4	5	6	7	8	
A	25.5	26.0	27.0	27.5	28.5	22.5	24.0	24.0	25.5	22.5-28.5
B	16.5	17.0	18.0	18.5	19.0	15.0	15.5	16.0	17.0	15 -19
C	29.0	30.0	32.0	33.0	36.0	25.5	27.5	28.0	29.0	25.5-36
D	26.5	26.0	28.0	28.0	28.0	24.0	24.5	25.0	26.0	24 -28
STC-20	7.0	11.0	--	15.0	17.0	5.5	10.0	10.5	11.0	5.5-17
30	16.0	20.0	--	24.5	26.0	14.0	19.0	18.5	19.0	14 -26
40	28.5	31.5	--	35.5	37.0	25.0	28.5	28.5	29.0	25 -37
60	61.0**	63.0**	--	64.0**	63.0**	50.5**	52.5	52.0	53.0	50.5-64

* Average of the difference in perceived noise level values calculated at 1000 and 2000 ft distances from aircraft.

** Differences calculated at 1000 ft distance only.

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APPENDIX C

EXPRESSION OF STEADY-STATE NOISE CRITERIA IN TERMS OF THE PERCEIVED NOISE LEVEL

Steady-state noise criteria for various types of rooms and work activities have been specified in a number of different ways; probably the most common methods of specifying criteria have been in terms of:

(a) The noise level as read by the "A" weighting network on the sound level meter.

(b) The speech interference level (SIL), defined as the arithmetic average of the sound pressure levels in the three octave frequency bands extending from 600 to 4800 cps. This number represents the average noise level over the frequency range most important from the standpoint of speech communication.

(c) Noise criteria (NC) curves, which are a family of curves defining octave band spectra. The curves, shown in Fig. C-1, are interpreted to mean that acceptable noise levels for a given space should not exceed the specified NC curve in <u>any</u> octave band. The value assigned to an NC curve equals the maximum permissible SIL value for the given curve.

The basis for selecting steady-state noise criteria differs. In many cases the criteria are based upon past experience, and measurement of noise levels in rooms judged to be acceptable by people using the rooms. In the case of SIL and NC criteria, the setting of acceptable noise limits is also guided by consideration of the masking effects of noise upon speech communication. And, in particular, the NC curves for offices are based upon studies involving noise measurements and extensive questioning of people in a

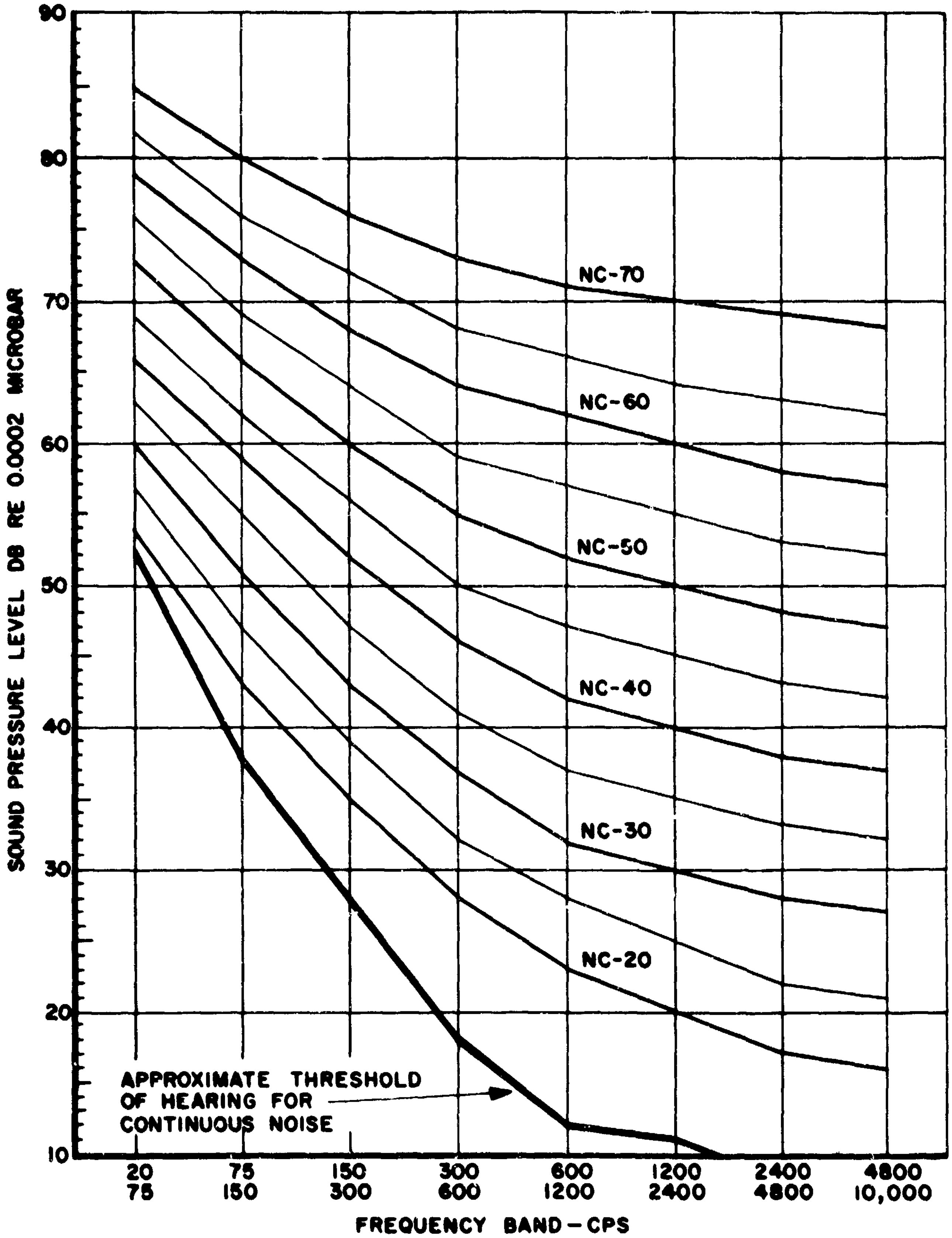

FIGURE C-1. NOISE CRITERION (NC) CURVES

number of offices.[22,23] These studies showed that both ease of speech communication and subjective feelings of noisiness were important in setting acceptable noise levels. As a result of these investigations, the NC curves were derived on the basis that the maximum loudness (as measured in phons) should not exceed the speech interference level by more than 22 units. If, instead of loudness, we calculate the noise levels in terms of noisiness or annoyance, as measured in PNdB, the NC curves reflect the requirement that perceived noise level (for an octave band noise spectra meeting the criterion curve in each octave band) should not exceed the speech interference level by more than 23 units.

When we describe aircraft noise levels in terms of a single number (the perceived noise level), we cannot specify criteria with quite the precision given by an NC curve. However, we can successfully incorporate the major NC curve concepts into perceived noise level criteria if we have some knowledge of the spectrum shape of the noise with which we are concerned. We thus interpret the NC curves as being based upon the two concepts that (1) for a given NC curve, the SIL value should not exceed the given NC value, (2) for this same criteria, the noisiness, expressed in PNdB, should not exceed the original NC value by more than 23 units. Thus, an NC-60 curve can be interpreted as meaning that the SIL should not exceed 60 dB and the perceived noise level should not exceed 83 PNdB. We must now use our knowledge of the type of noise spectra to establish a relationship between perceived noise levels and SIL values.

To establish this relationship, the generalized noise spectra for various types of aircraft flyovers, discussed in Appendix A, were analyzed to obtain differences between perceived noise level and SIL values. These differences for "indoor" noise spectra (obtained by subtracting typical building noise reduction value from the generalized flyover noise spectra produced by different types of aircraft) vary not only with the type of aircraft operation, but also with the magnitude of the speech interference level and perceived noise level. For takeoff noise spectra, the difference between perceived noise level and speech interference level varied from about 38 dB, at low SIL values, to 25 dB at relatively high SIL values. And, for approach spectra, the corresponding values range from about 26 dB at low SIL values decreasing to 20 dB at high SIL values.

On the basis of the above range of differences, in order to insure that SIL values will not exceed the values implied by the original NC ratings, one must use the minimum value of 20 dB to relate the NC curve to perceived noise level criteria. Thus, in translating NC criteria into terms of perceived noise level criteria, we have adopted the conservative relationship that:

$$\text{PNL (criteria)} = \text{NC (criteria)} + 20 \qquad \text{(C-1)}$$

On the basis of the above rule, we might review how our criteria expressed in PNdB meets our objective of having both noisiness and speech interference levels remain below given limits. If, for example, we assume an outside noise level produced by aircraft flyovers of 100 PNdB with a criterion of 60 PNdB selected for a space inside the building (implying also, that the SIL in the room should not exceed 40 dB) we would require a building noise reduction of 40 PNdB. If we choose a building construction which meets our 40 PNdB noise reduction requirements for takeoff noise, the resulting noise inside the building would be 60 PNdB with a speech interference level ranging from approximately 22 to 35 dB for takeoff noise; for approach noise, the noise would range from 55 to 60 PNdB with SIL values from 29 to 35 dB.*

If we were concerned only about noise produced under the approach path of commercial turbojet or turbofan aircraft, we could take advantage of the rule (given in Step 9) that the noise reduction achieved by a given wall will be about 5 PNdB greater for such noise than for takeoff noise, hence, we could use a somewhat lighter wall to achieve our needed 40 PNdB reduction. With this lighter wall, the approach noise produced by commercial turbojet or turbofan aircraft would produce SIL values inside the room ranging from 34 to 40 dB. In either case, the perceived noise level does not exceed 60 PNdB, nor does the speech interference level exceed 40 PNdB, thus meeting our noisiness and SIL requirements for the noise criterion.

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* This example assumes that the building noise reduction curve has a frequency spectrum shape not drastically different than those used in calculations discussed in Appendix B.

* U. S. GOVERNMENT PRINTING OFFICE : 1968 O 777-003